Physics 111 - Class 3B
Kinematics II

Do not draw in/on this box!

September 21, 2022

Class Outline

- Logistics / Announcements
- Debrief on Calculus in Phys 111
- From Position to Velocity
- Worked Problems
- HW3 tips
- Resource: Moving Person Simulation

Logistics/Announcements

- Lab this week: Pre-lab 2 Video - Deriving Projectile Motion Equation
- HW due this week on Thursday at 6 PM
- Learning Log 3 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Bonus Test 1 available this week

Logistics/Announcements

- Tutorials started last week !
  - Anybody can go to any Tutorial, see the schedule on the SSC
  - Attendance is not required in Tutorials
  - The TAs will guide you through a long problem each week
  - The problem is also available on PrairieLearn, but will not be graded (and is not for any marks)

Tutorial Problem this week

2. A position vs. time graph is shown. On the velocity versus time graph below it sketch the corresponding velocity as a function of time. Show all calculations, and label the axes appropriately. /9

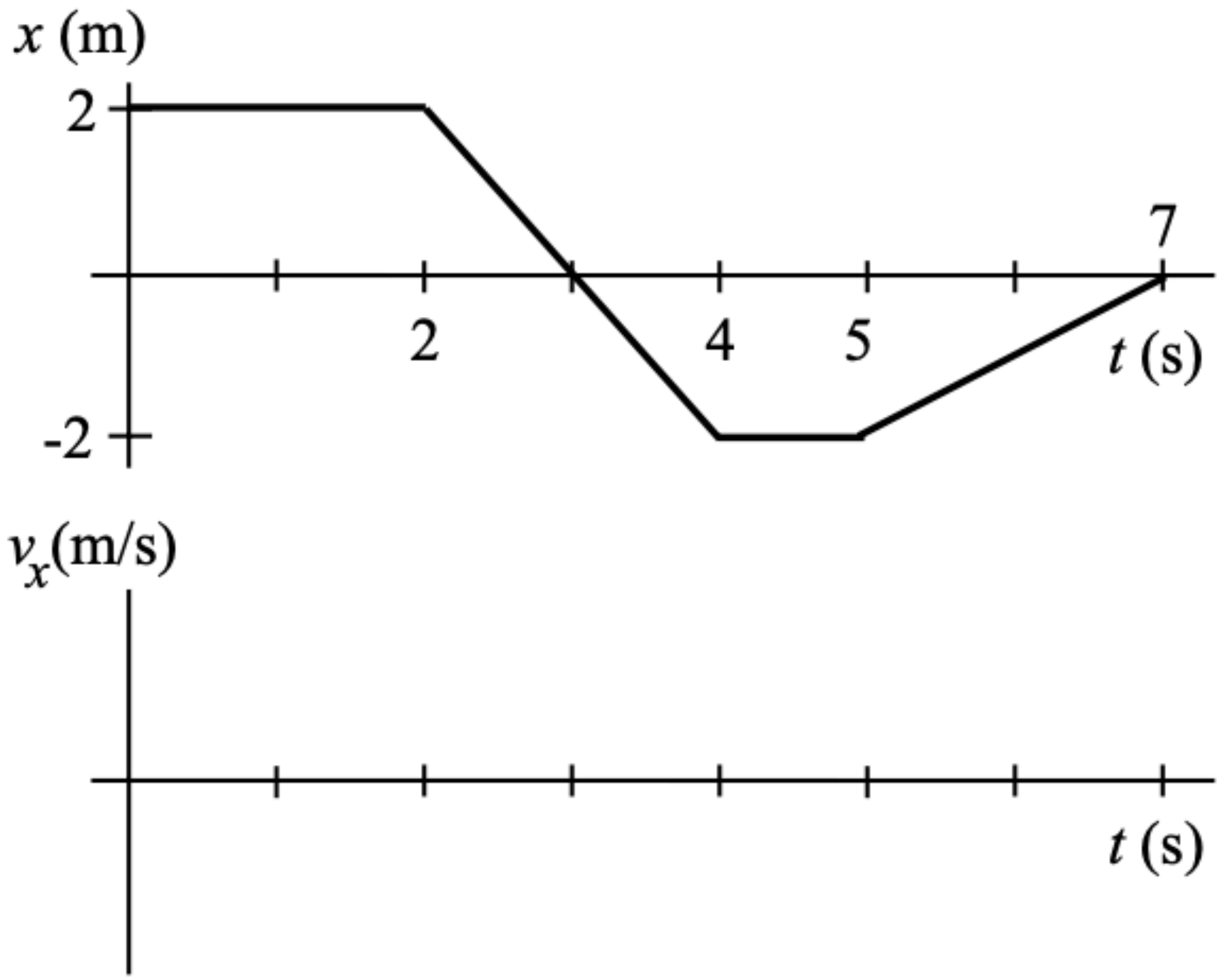

FIG. 1:

Tutorial Problem this week

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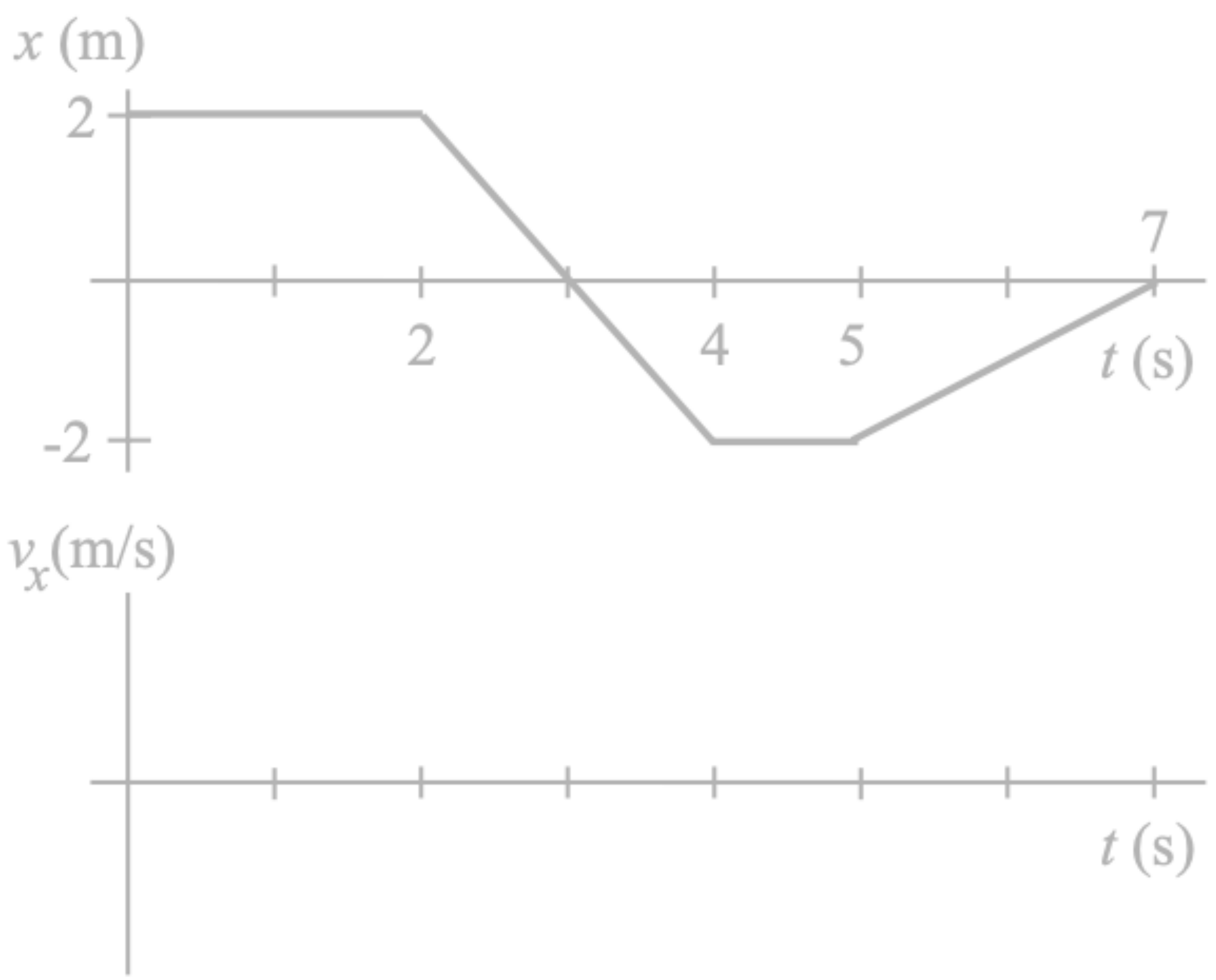

FIG. 1:

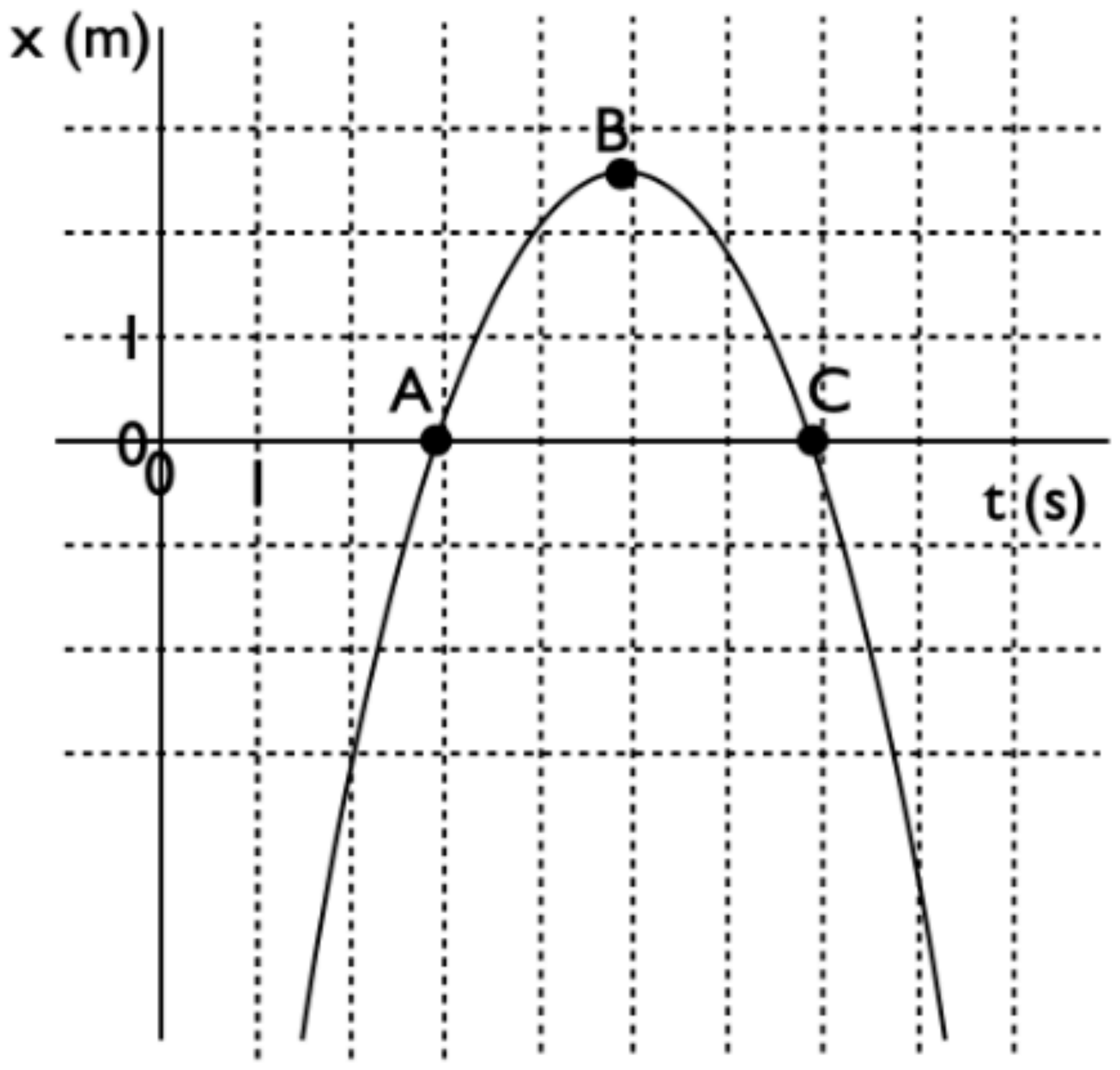

FIG. 1:

3. (a) At each of A, B and C on Fig. 1, estimate the x-component of the velocity vector, v_x from the position vs. time graph (/3) . Draw a tangent line to the graph at each location (/3) and show the calculation of its slope (/3).

(b) What sign, if any, does the x-component of the acceleration vector, a_x, have at point B (/2)?

Test 1 Feedback

- Make sure to **review** your test carefully!
- Many of you think “sig figs” or “sig digs” were the reason you got questions wrong, that is NOT! the case. Your answer will be accepted if it’s within a threshold (~ 5%).
    - Usually the issue is negative signs, directions, calculation errors, swapping components (x-y instead of y-x, etc...)
- Go to the Tutorials, or come to my student hours to get help on solving your questions

Test 1 Feedback

Vector Components

For this question, consider two vectors $\vec{A}$ and $\vec{B}$ that are orthogonal to each other.

Part 1

What is the component of $\vec{B}$ along the direction of $\vec{A}$?

- (a) 1
- (b) A sin θ
- (c) 0
- (d) B cos θ

Part 2

What is the component of $\vec{A}$ along the direction of $\vec{B}$?

- (a) 0
- (b) 1
- (c) A sin θ
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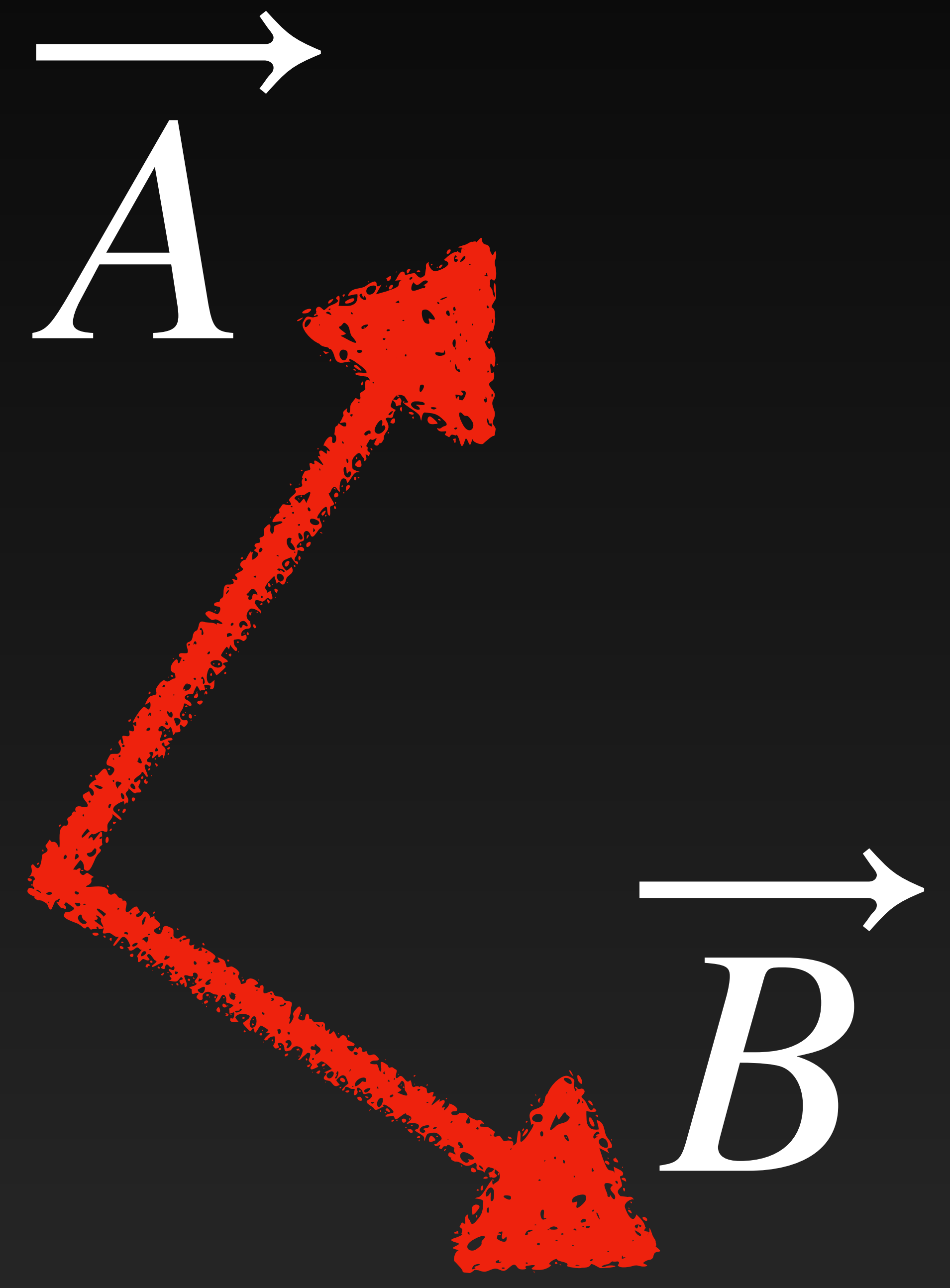
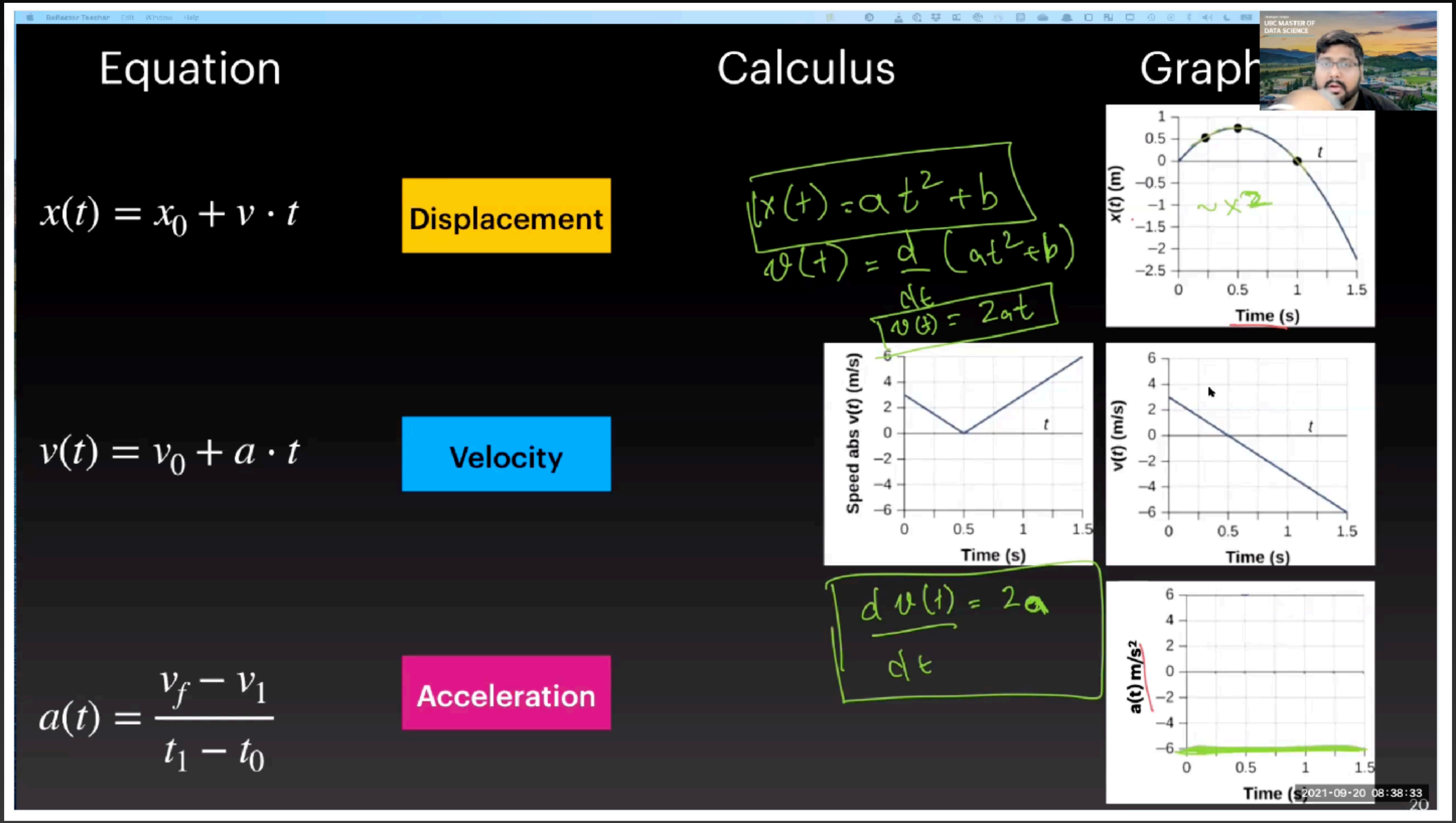


"Component of one vector along the direction of another is the same as a "Dot Product".

Monday's Class Video

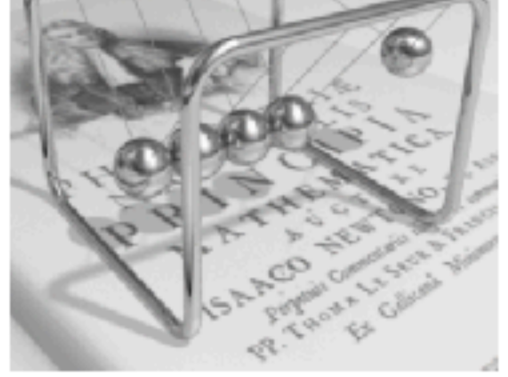


Debrief

Displacement x(t)	Velocity v(t)	Acceleration a(t)
$x(t) = 4t^2 + 3t + 2$	$v(t) = 8t + 3$	$a(t) = 8$
$x(t) = 2t^2 + 8$		
$x(t) = 8t^3 + 3t$	$v(t) = 24t^2 + 3$	
$x(t) = -t^3 + 5t^2 + 3t$		

Debrief

Displacement x(t)	Velocity v(t)	Acceleration a(t)
$x(t) = 4t^2 + 3t + 2$	$v(t) = 8t + 3$	$a(t) = 8$
$x(t) = 2t^2 + 8$	$v(t) = 4t$	$a(t) = 4$
$x(t) = 8t^3 + 3t$	$v(t) = 24t^2 + 3$	$a(t) = 48t$
$x(t) = -t^3 + 5t^2 + 3t$	$v(t) = -3t^2 + 10t + 3$	$a(t) = -6t + 10$



Physics 111

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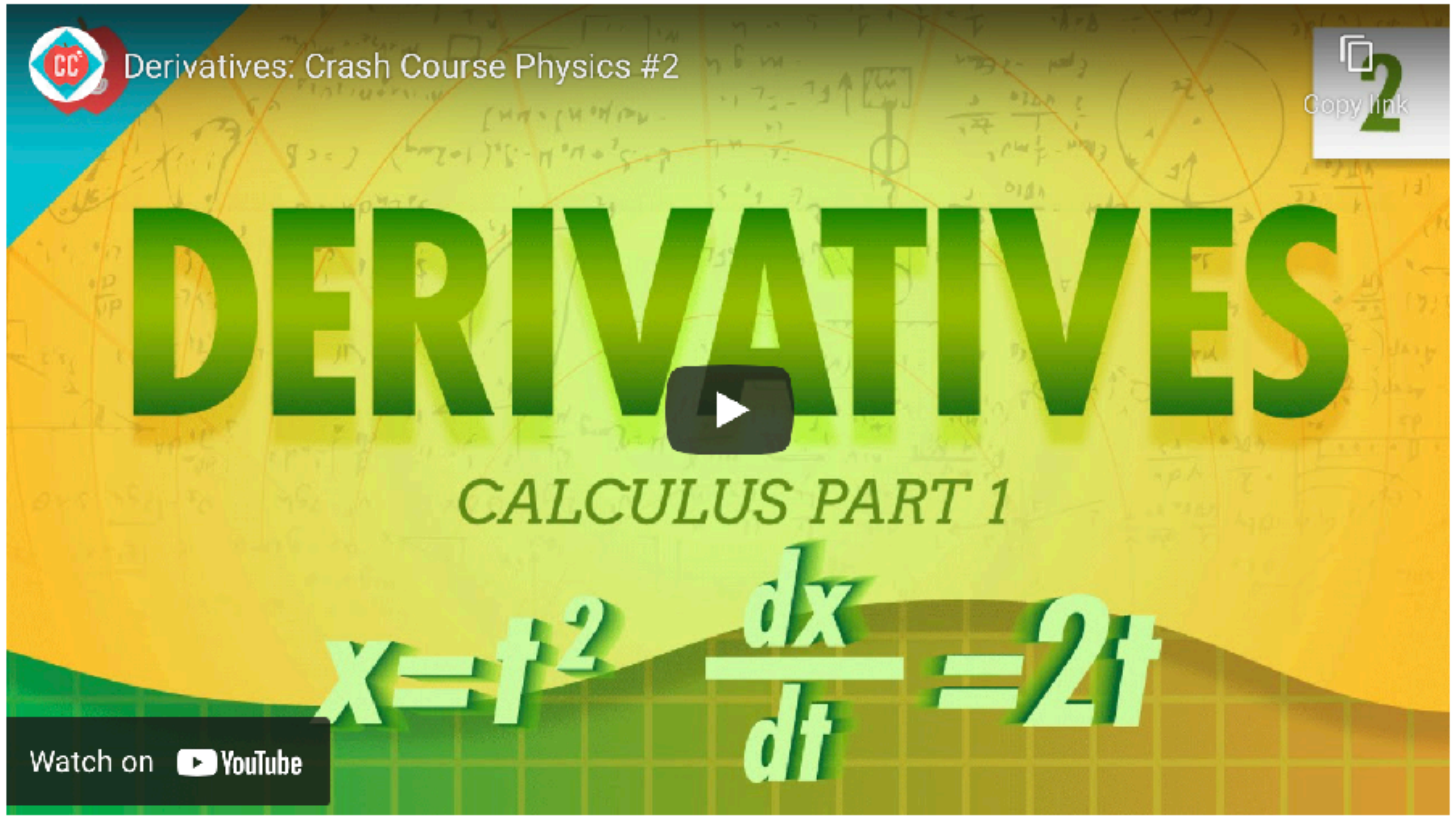
Videos

Below are the assigned videos for this week. The videos are collapsible so once you're done with one, you can move to the next one. In the sidebar on the right, you can use the checklists to keep track of what's done.

Summary of Calculus from Crash Course Physics

Derivatives



Integrals

Required Videos

Contents

Checklist of items

- [ ] Calculus: Derivatives
- [ ] Calculus: Integrals
- [ ] Vectors and 2D Motion
- [ ] Introduction to Displacement and the Differences Between Displacement and Distance
- [ ] Introduction to Velocity and Speed and the differences between the two
- [ ] Introduction to Acceleration with Prius Brake Slamming Example Problem
- [ ] Introduction to Free-Fall and the Acceleration due to Gravity

Table of contents

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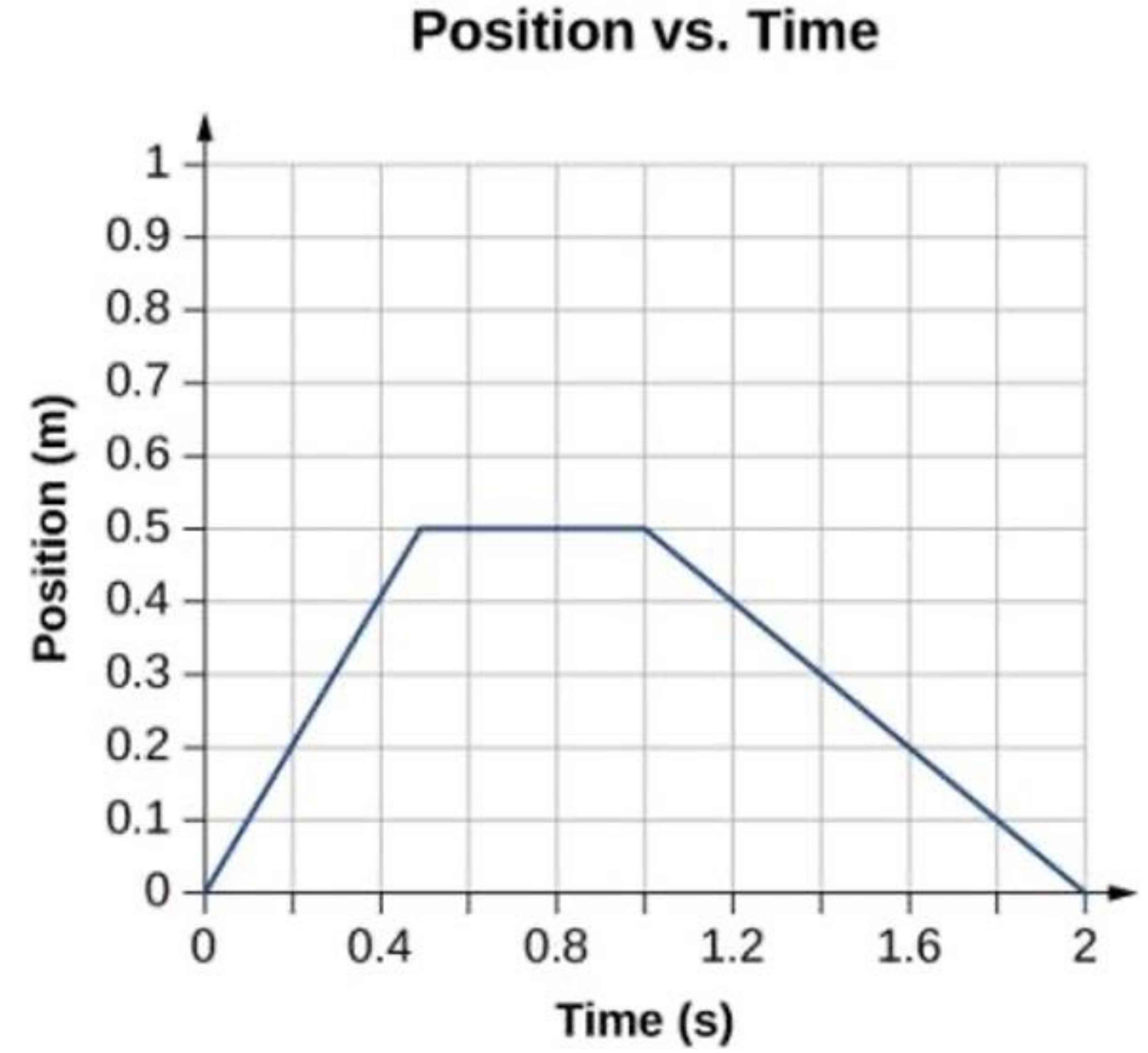
My highlights

Figure 3.1 A JR Central L0 series five-car maglev (magnetic levitation) train undergoing a test run on the Yamanashi Test Track. The maglev train's motion can be described using kinematics, the subject of this chapter. (credit: modification of work by "Maryland GovPics"/Flickr)

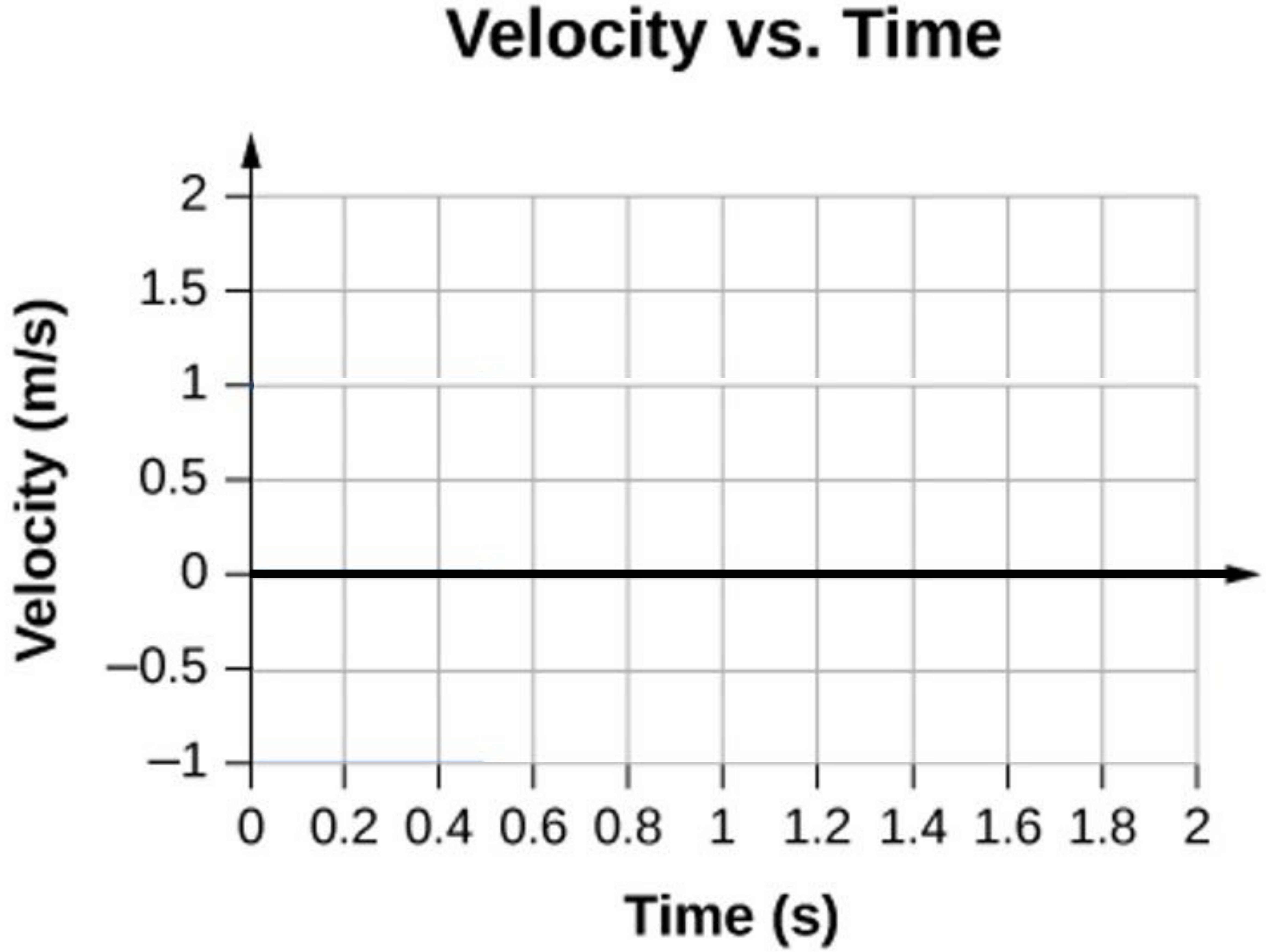
Chapter Outline

Our universe is full of objects in motion. From the stars, planets, and galaxies; to the motion of people and animals; down to the microscopic scale of atoms and molecules—everything in our universe is in motion. We can describe motion using the two disciplines of kinematics and dynamics. We study dynamics, which is concerned with the causes of motion, in Newton's Laws of Motion; but, there is much to be learned about motion without referring to what causes it, and this is the study of kinematics. Kinematics involves describing motion through properties such

Position Graph to Velocity Graph



The object starts out in the positive direction, stops for a short time, and then reverses direction, heading back toward the origin. Notice that the object comes to rest instantaneously, which would require an infinite force. Thus, the graph is an approximation of motion in the real world. (The concept of force is discussed in Newton's Laws of Motion.)



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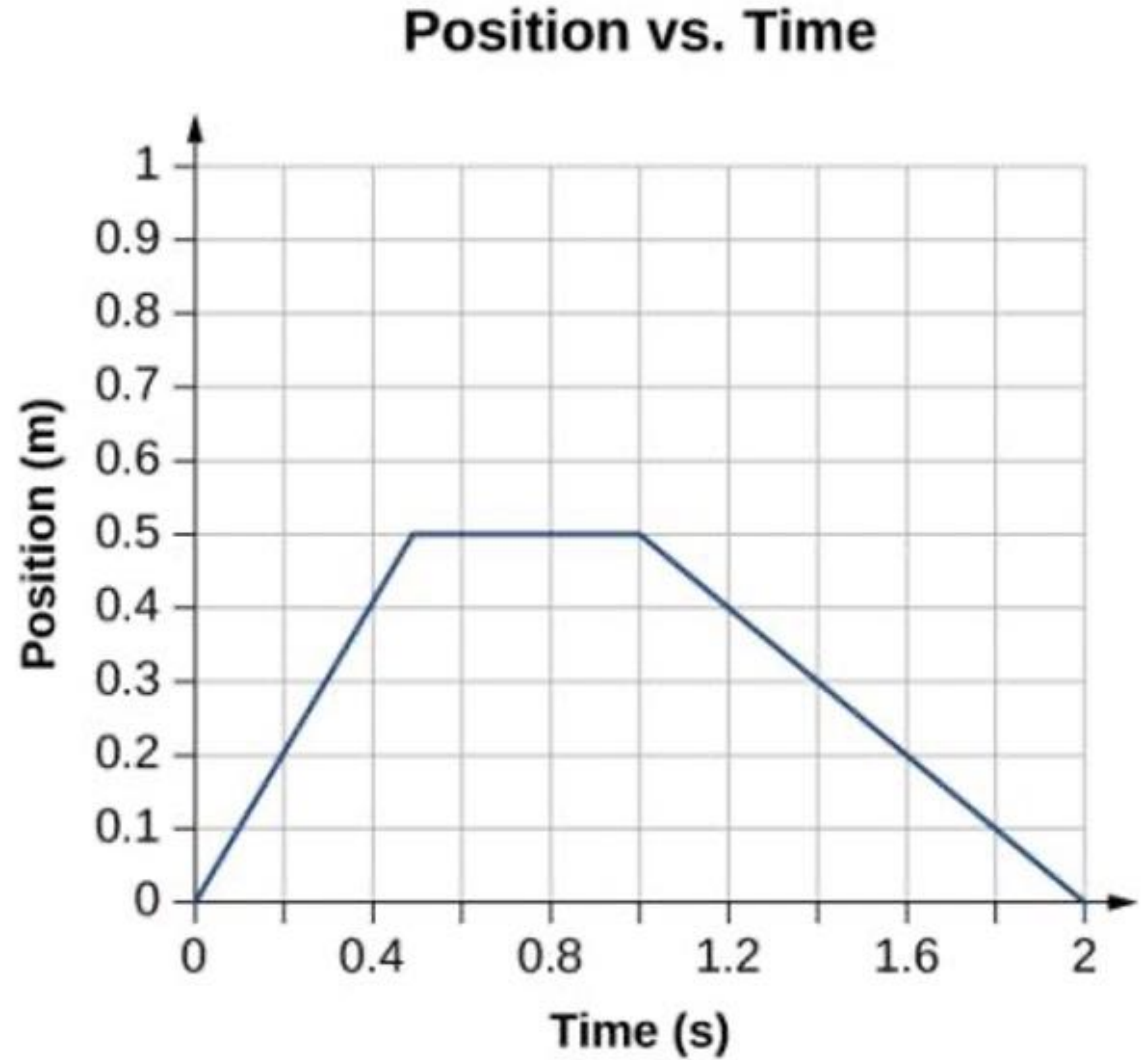

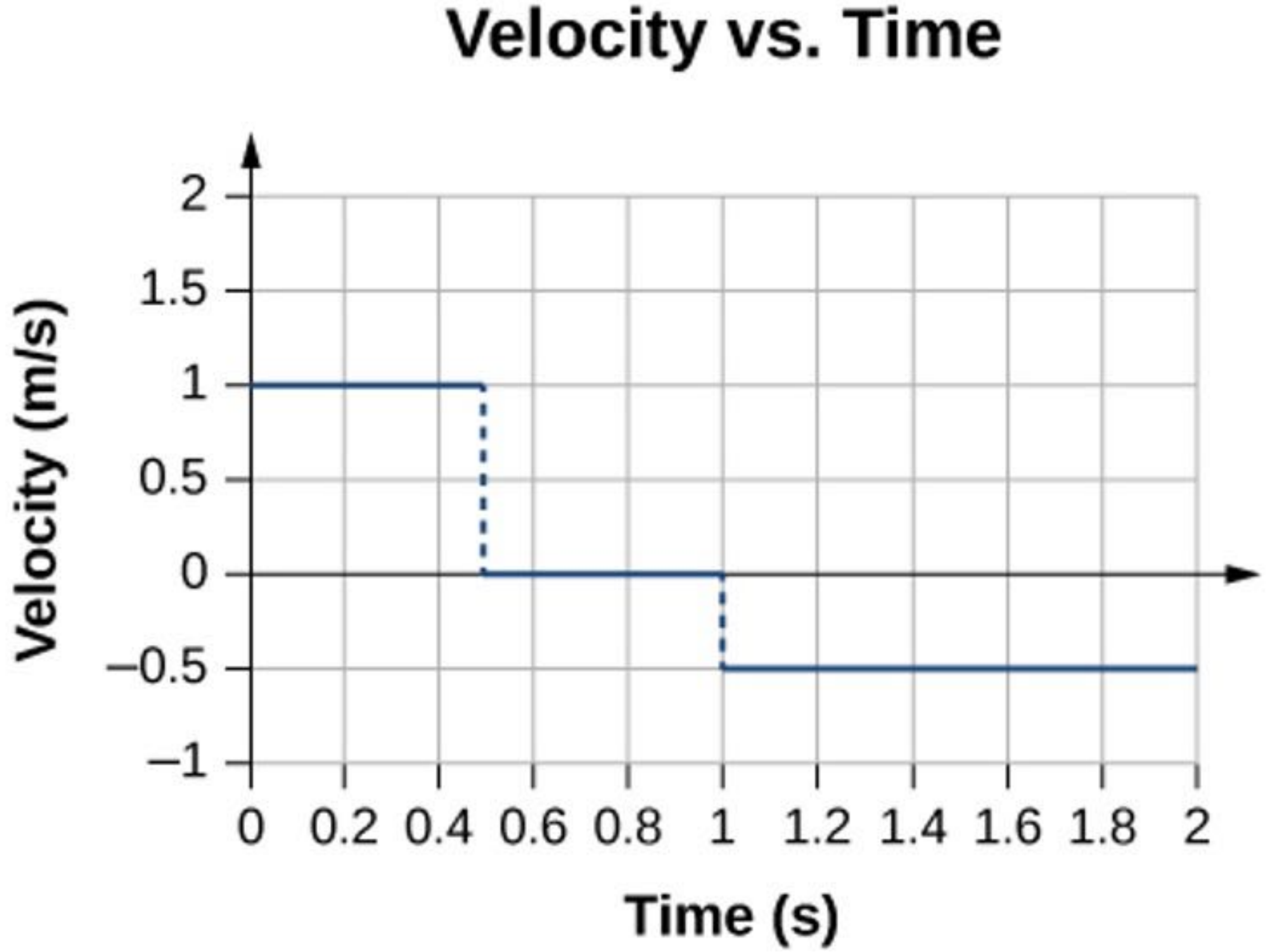

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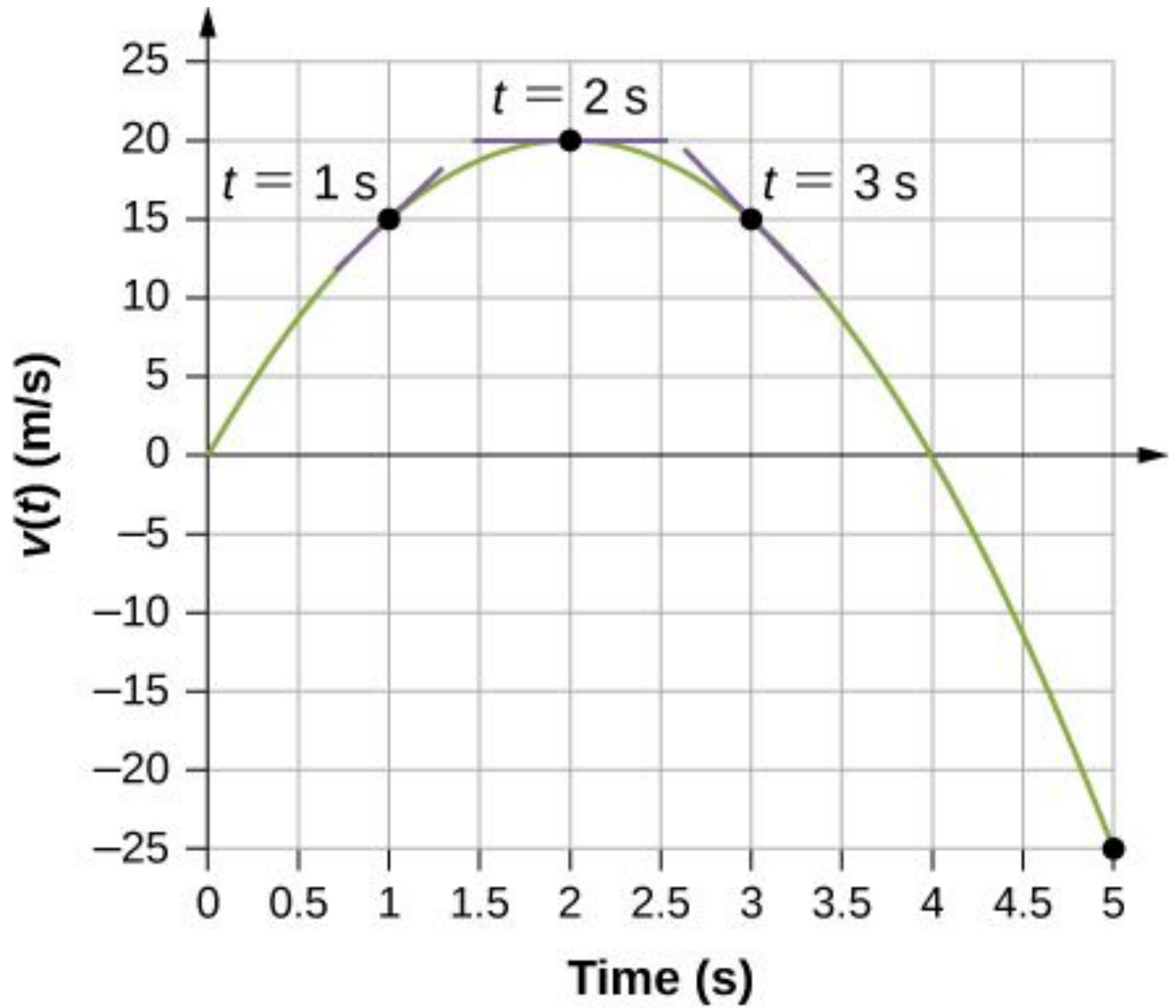
Velocity Graph to Acceleration Graph

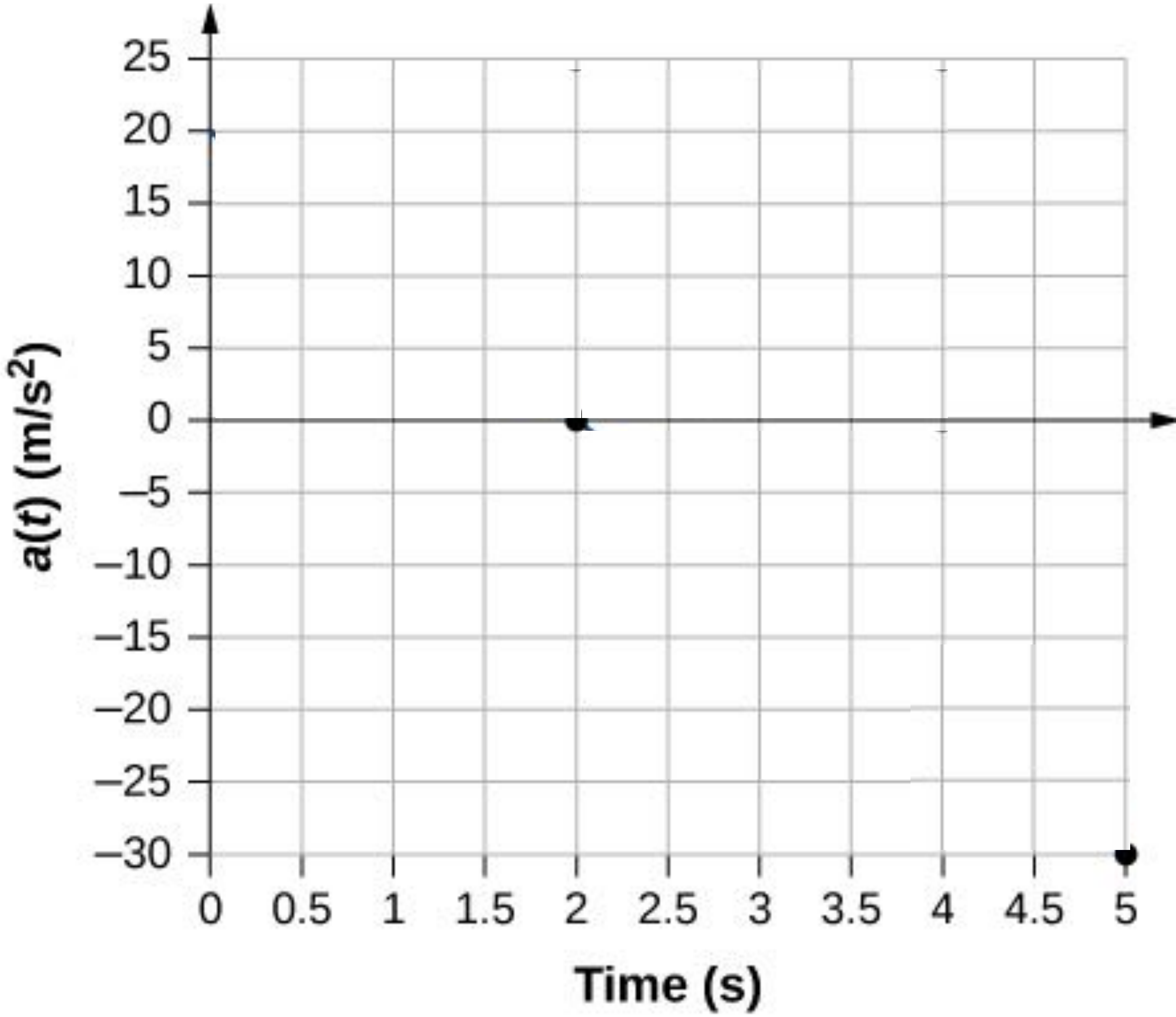
EXAMPLE 3.6

Calculating Instantaneous Acceleration

A particle is in motion and is accelerating. The functional form of the velocity is $v(t) = 20t - 5t^2$ m/s.

a. Find the functional form of the acceleration.
b. Find the instantaneous velocity at t = 1, 2, 3, and 5 s.
c. Find the instantaneous acceleration at t = 1, 2, 3, and 5 s.
d. Interpret the results of (c) in terms of the directions of the acceleration and velocity vectors.





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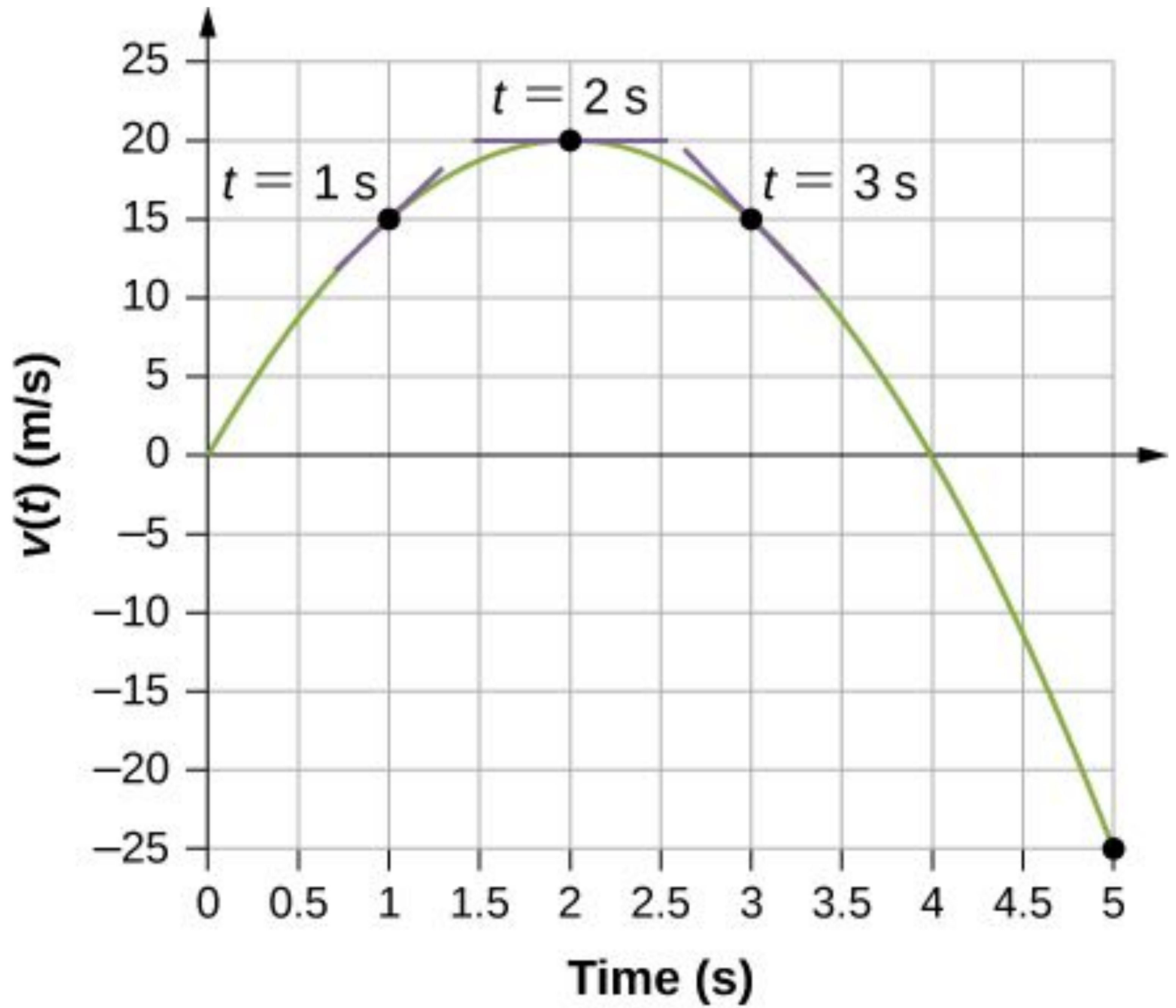

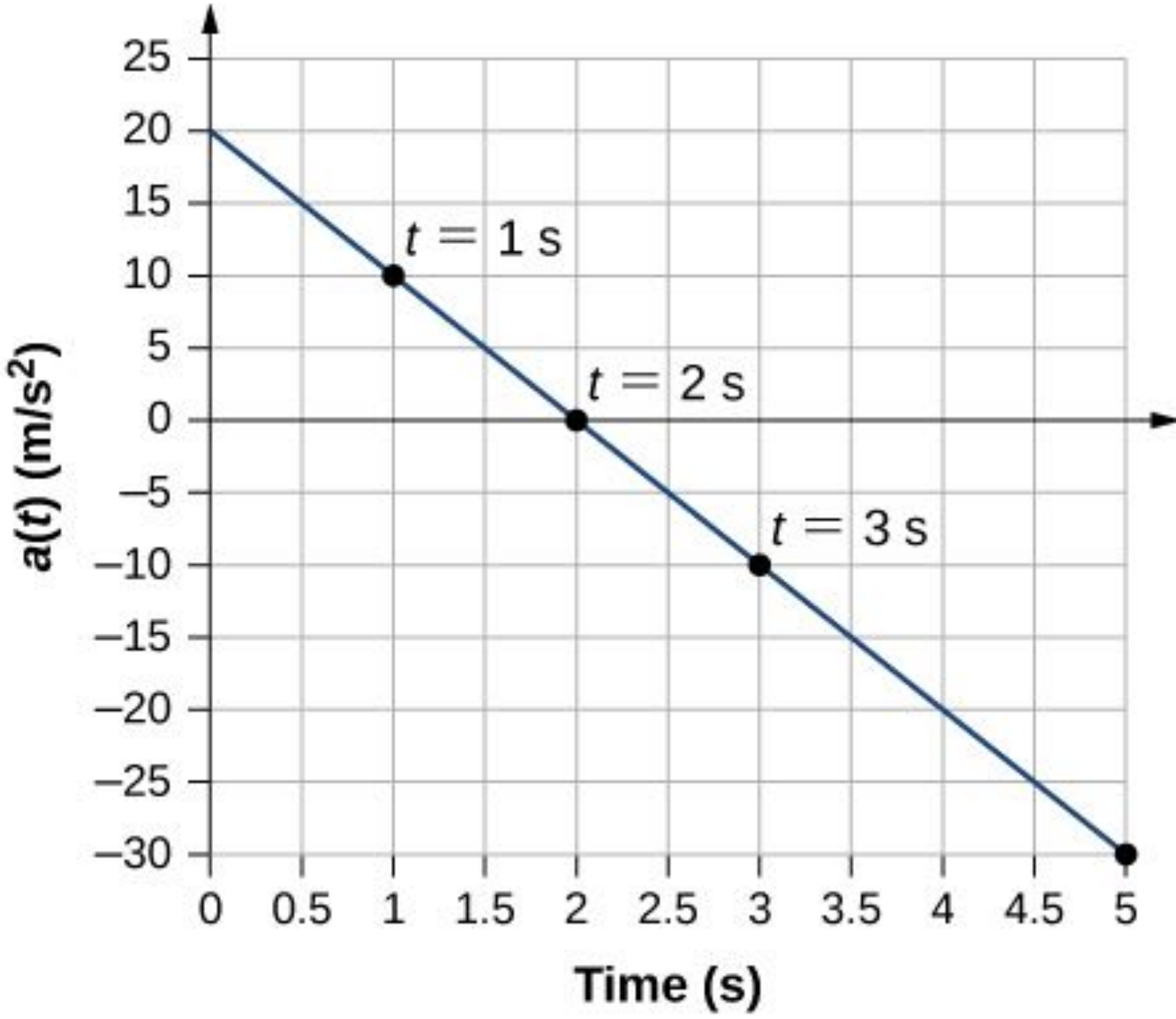

Key Equations

Displacement	$\Delta x = x_{\mathrm{f}} - x_{\mathrm{i}}$
Total displacement	$\Delta x_{\mathrm{Total}} = \sum \Delta x_{\mathrm{i}}$
Average velocity (for constant acceleration)	$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$
Instantaneous velocity	$v(t) = \frac{dx(t)}{dt}$
Average speed	$\text{Average speed} = \bar{s} = \frac{\text{Total distance}}{\text{Elapsed time}}$
Instantaneous speed	$\text{Instantaneous speed} = \lvert v(t) \rvert$
Average acceleration	$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$
Instantaneous acceleration	$a(t) = \frac{dv(t)}{dt}$
Position from average velocity	$x = x_0 + \bar{v}t$

Key Equations

Average velocity	$\bar{v} = \frac{v_0 + v}{2}$
Velocity from acceleration	$v = v_0 + at \quad (\text{constant } a)$
Position from velocity and acceleration	$x = x_0 + v_0 t + \frac{1}{2}at^2 \quad (\text{constant } a)$
Velocity from distance	$v^2 = v_0^2 + 2a(x - x_0) \quad (\text{constant } a)$
Velocity of free fall	$v = v_0 - gt$ (positive upward)
Height of free fall	$y = y_0 + v_0 t - \frac{1}{2}gt^2$
Velocity of free fall from height	$v^2 = v_0^2 - 2g(y - y_0)$
Velocity from acceleration	$v(t) = \int a(t)dt + C_1$
Position from velocity	$x(t) = \int v(t)dt + C_2$

Worked Problems

EXAMPLE 3.15

Vertical Motion of a Baseball

A batter hits a baseball straight upward at home plate and the ball is caught 5.0 s after it is struck Figure 3.28. (a) What is the initial velocity of the ball? (b) What is the maximum height the ball reaches? (c) How long does it take to reach the maximum height? (d) What is the acceleration at the top of its path? (e) What is the velocity of the ball when it is caught? Assume the ball is hit and caught at the same location.

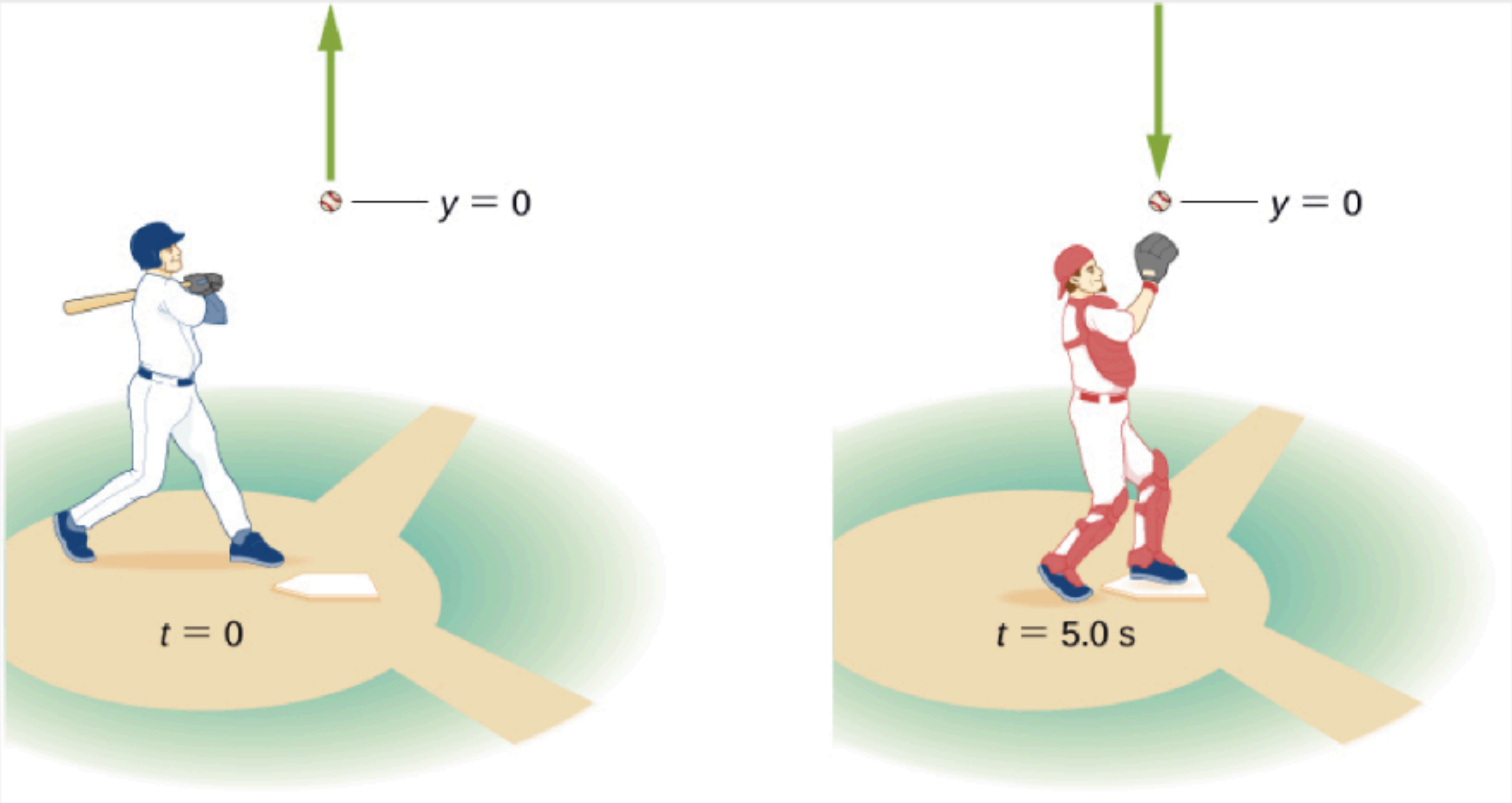

Figure 3.28 A baseball hit straight up is caught by the catcher 5.0 s later.

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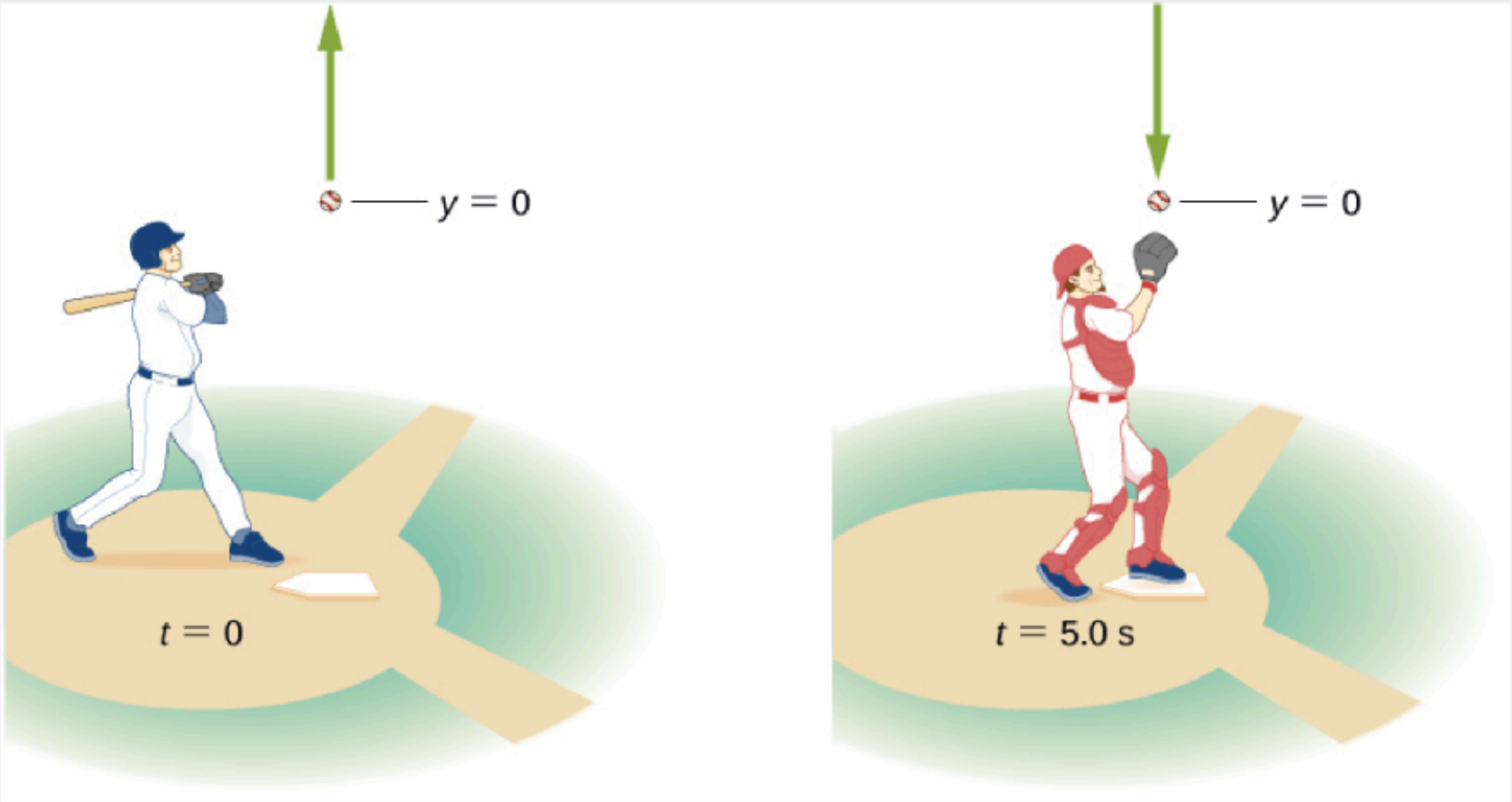

Figure 3.28 A baseball hit straight up is caught by the catcher 5.0 s later.

Solution

a. Equation 3.16 gives

$$y = y_0 + v_0 t - \frac{1}{2} g t^2$$

$$0 = 0 + v_0(5.0\ \text{s}) - \frac{1}{2}\left(9.8\ \text{m/s}^2\right)(5.0\ \text{s})^2,$$

which gives $v_0 = 24.5\ \text{m/s}$.

b. At the maximum height, $v = 0$. With $v_0 = 24.5\ \text{m/s}$, Equation 3.17 gives

$$v^2 = v_0^2 - 2\,g(y - y_0)$$

$$0 = (24.5\ \text{m/s})^2 - 2(9.8\ \text{m/s}^2)(y - 0)$$

or

$$y = 30.6\ \text{m}.$$

c. To find the time when $v = 0$, we use Equation 3.15:

$$v = v_0 - gt$$

$$0 = 24.5\ \text{m/s} - (9.8\ \text{m/s}^2)t.$$

This gives $t = 2.5\ \text{s}$. Since the ball rises for 2.5 s, the time to fall is 2.5 s.

d. The acceleration is 9.8 m/s^2 everywhere, even when the velocity is zero at the top of the path. Although the velocity is zero at the top, it is changing at the rate of 9.8 m/s^2 downward.

e. The velocity at $t = 5.0\text{s}$ can be determined with Equation 3.15:

$$\begin{aligned} v &= v_0 - gt \\ &= 24.5\ \text{m/s} - 9.8\ \text{m/s}^2(5.0\ \text{s}) \\ &= -24.5\ \text{m/s}. \end{aligned}$$

CHECK YOUR UNDERSTANDING 3.7

A chunk of ice breaks off a glacier and falls 30.0 m before it hits the water. Assuming it falls freely (there is no air resistance), how long does it take to hit the water? Which quantity increases faster, the speed of the ice chunk or its distance traveled?

CHECK YOUR UNDERSTANDING 3.7

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$$t = 2.47 \text{ s}$$

"Distance travelled" increases faster…

HW 3 Tips

HW3.2. Throwing Stones

Mateo simultaneously throws two stones from the top edge of a building with a speed 28.4 m/s. They throw one straight down and the other straight up.

The first one hits the street in a time t_1. How much later is it before the second stone hits?

$\Delta t =$	number (3 significant figures)	s	?

HW 3 Tips

Rocket

A rocket has a velocity (pointing away from the launch pad) given by $v(t)$=6t-t^2 where x is in meters, and t is in seconds.

Please enter in fractions rather than decimals when applicable (e.g. use 1/2 rather than 0.5)

Part 1

(a) If the rocket started at height $x(0)$ = 0, What is the height as a function of time in m?

symbolic expression ?

HW 3 Tips

Velocity and Acceleration of an Object

If the velocity of an object in one-dimensional motion is given by $v(t) = -5t^2 - 4t$, where the units of v are in m/s and of t are in seconds,

The velocity and acceleration of the object at $t =$ 6.12 s are:

See you next class!

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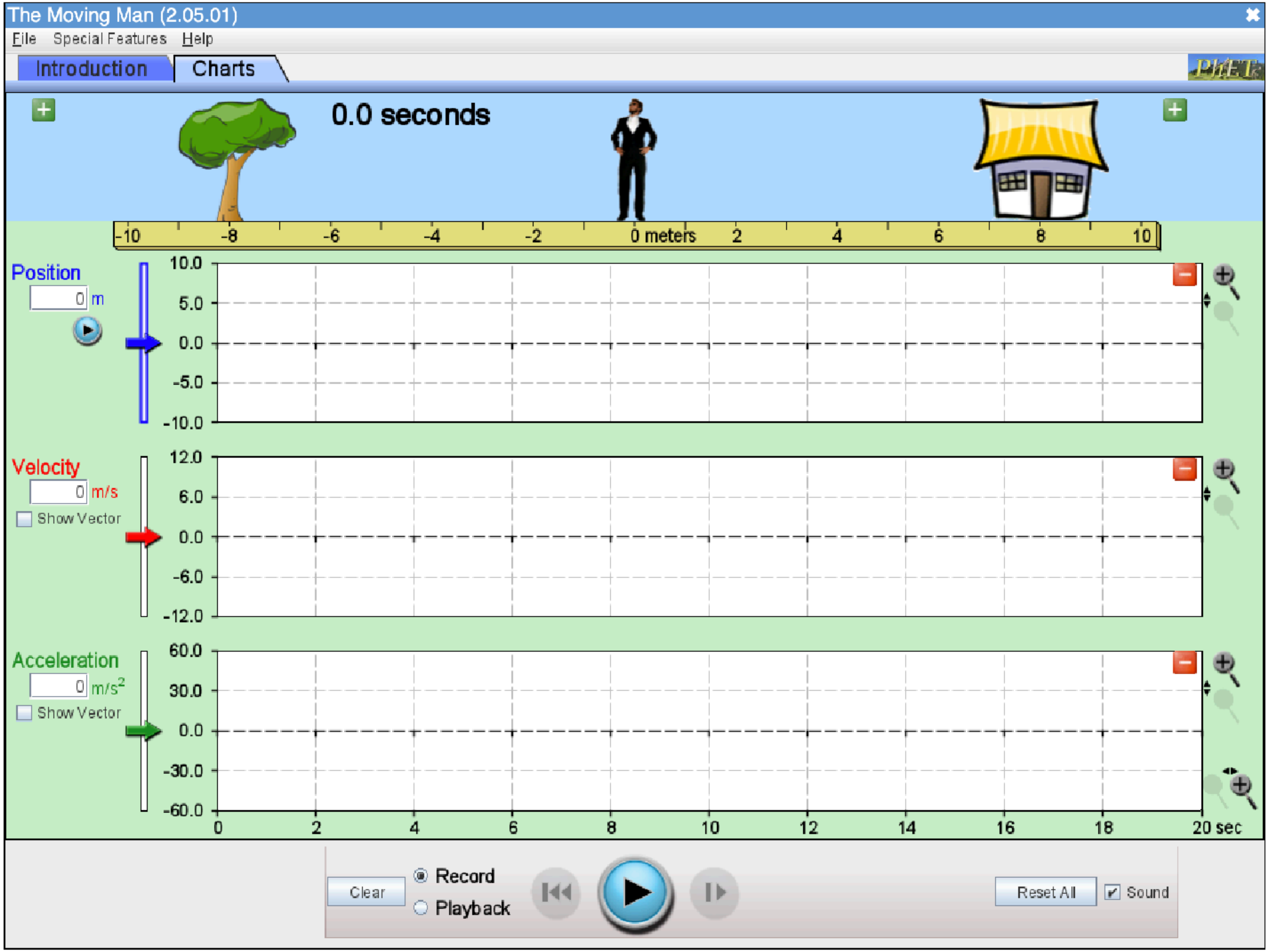
Simulation


The Moving Man (2.05.01)
File
Special Features
Help
Introduction
Charts
0.0 seconds
-10
-8
-6
-4
-2
0 meters
2
4
6
8
10
Position
0 m
10.0
5.0
0.0
-5.0
-10.0
Velocity
0 m/s
Show Vector
12.0
6.0
0.0
-6.0
-12.0
Acceleration
0 m/s²
Show Vector
60.0
30.0
0.0
-30.0
-60.0
0
2
4
6
8
10
12
14
16
18
20 sec
Clear
Record
Playback
Reset All
Sound