

NAME \_\_\_\_\_ PARTNER \_\_\_\_\_  
DATE \_\_\_\_\_ TA \_\_\_\_\_ LAB DAY/TIME \_\_\_\_\_

## KINEMATICS LAB 1: POSITION AND VELOCITY

### Introduction

In this lab, you will produce position and velocity graphs by walking in front of a motion detector. The main idea is for you to become comfortable at translating back and forth between graphs and real-life motion. At the end we'll do something a little different just for fun.

In most courses, lab and discussion sections are separate activities. But we deliberately combine hands-on activities with worksheet-style conceptual questions. That way, you can continually integrate your hands-on experiences with more abstract knowledge, leading to deeper understanding.

If you took honors high school physics, much of this lab will be review. Since some students never took physics before, however, we want to make sure that everyone gets up to speed (excuse the pun!) on this crucial material. We've also included some starred questions that should challenge everyone, and some harder challenge questions marked with a double star. You might want to save some of these harder questions—especially the double starred ones—until after you've completed the rest of the lab.

### A Note About Predictions

Throughout your physics labs, you will be asked to make predictions about the outcome of most experiments before you do them. **The correctness of these predictions will never be graded.** We do not expect you to *know* what a particular outcome will be before you do an experiment, but we do expect you to *think* about, predict, and record your prediction for what the outcome will be. This technique of “predict before doing” is designed to keep everyone actively thinking about the concepts, and to help you focus on those areas you may not yet fully understand. (We would much rather have you make the errors you need to make *here*, in lab and discussion section, rather than on an exam.) Whenever you and your lab partner disagree about a prediction, see if you can understand why—you'll both benefit.

We force you to make these predictions because we want you learn as much as possible from each lab. We know that that's much more likely to happen if you're actively engaged throughout each session, making sense of your own beliefs and preconceptions at each stage. If a particular outcome doesn't match your prediction, by explaining why you'll learn something—and that's the whole point! Otherwise it's just too easy to work your way through the labs without ever really thinking about what's going on. Indeed, in the past some students have gotten exam questions wrong because they *misremembered* what they saw in lab, answering with what they thought *should* have happened rather than with what really happened. Reconciling what you expect with what really happens—while in lab—will help you avoid this problem.

While you will never lose credit for making an incorrect prediction, you *will* lose credit if you don't make predictions beforehand, or if you go back and change your predictions later to match the outcome. We are very serious about this: **you must make predictions beforehand, and you cannot go back and change them later.** Altering them afterwards to match the outcome just makes the whole process silly, not to mention raising questions about your scientific integrity.

## Equipment

Onto the experiments!

First, make sure the LabPro box has power: you should see a small green light on both it and the MotionDetector2.

Open the "Kinematics Lab 1A" file on the desktop. This should start the LoggerPro software.

Place the MotionDetector on the table so that you can walk several meters in front of it without crashing into anyone or anything. If possible, make sure you can see the computer screen while you're walking. For the following, one lab partner should hit the "Collect" button on the screen, while the other partner walks in front of the detector. Swap roles so each of you gets to do some walking.

To help the detector "see" your motion clearly as you walk in front of it, try:

--shuffling your feet.

--carrying a large book or notebook in front of you facing the detector.

### How the Motion Detector Works

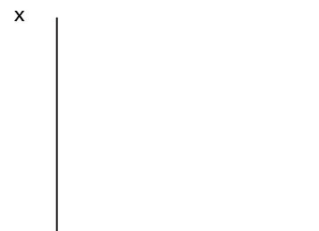
The Motion Detector measures the distance from itself to the nearest object in front of it. To determine distances, the detector emits and receives pulses of ultrasound. Since the speed of sound in room temperature air is known, the detector can calculate the distance of an object by timing how long the pulse takes to reflect off an object and return to the detector. (This is similar to how a bat "sees" using sound. It is also how a Polaroid auto focus camera determines the distance to an object to focus properly.) The detector does not work for objects closer to 0.4 meters. In order to provide information about velocity and acceleration, the motion detector makes several measurements and the computer calculates the values.

The clicking sound that the detector makes is not the ultrasound used to determine the distance to an object, but is instead a by-product of the mechanism that produces the sound. Most people cannot hear the frequencies used by the Motion Detector.

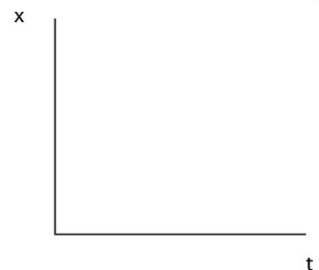
## I. Distance graphs

In this warm-up activity, you will make position vs. time graphs for different walking speeds and directions. The detector is the *origin* from which distances are measured. When you are ready to start graphing distance, click once on the **Collect** button in the upper right corner of the screen. The detector starts graphing a moment later, when you hear it clicking.

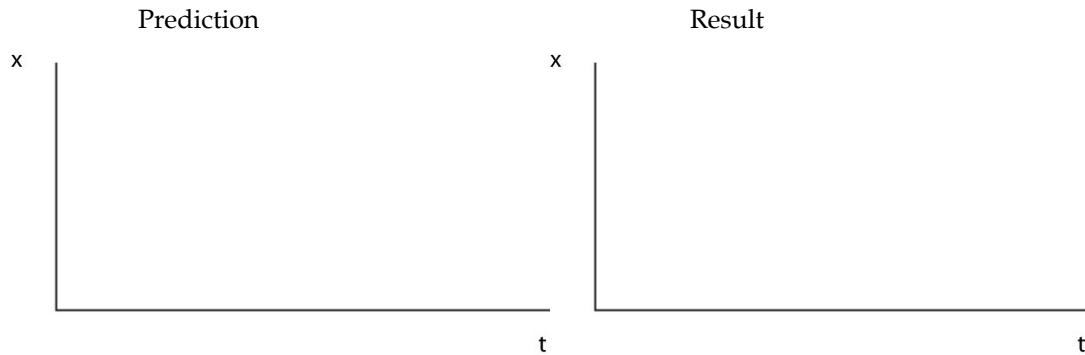
- ♦ Starting about one-quarter a meter from the detector, make a distance vs. time graph, walking away from the detector (origin) *slowly and steadily*. Sketch the graph on the right.



- ♦ Make a distance vs. time graph, walking away from the detector (origin) *medium fast and steadily*. Sketch the graph.

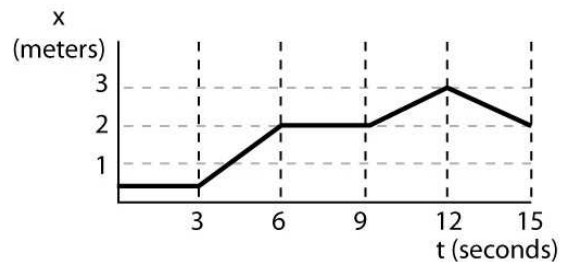


- Suppose you walk away from the detector slowly and steadily for a few seconds, stop for a few seconds, and then walk toward the detector quickly. What will the position vs. time graph look like? **Sketch your prediction about the graph, *before* obtaining the result. Remember: you lose no points for making incorrect predictions; you will lose points if you don't make a prediction, or if you change your prediction later.**



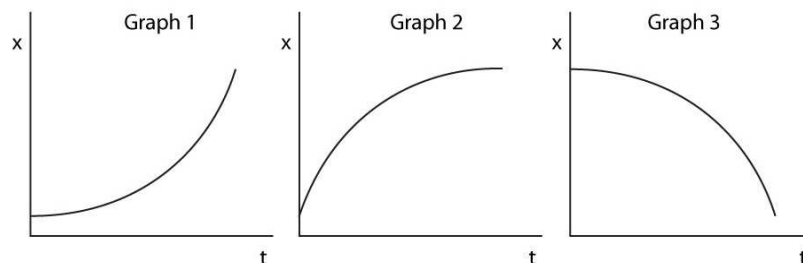
♦ Do the experiment a few times, if needed, to get a clean run. Sketch the result above.

- Briefly describe how you would walk to make the position graph drawn here.



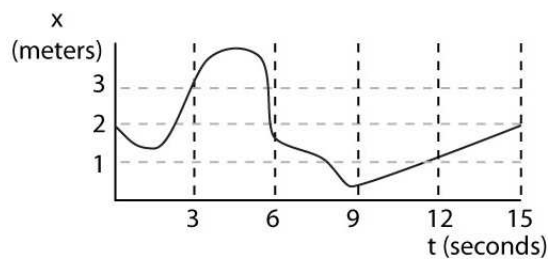
♦ Then try to reproduce this position vs. time graph. Make sure each lab partner takes a turn walking. Don't worry if your times or distances disagree slightly with the times and distances on this graph.

- Describe in words how you can walk to produce graphs 1 through 3, as drawn here. Write your answer before walking each.



- ♦ Try it out. For graph 2, you may want to begin your walk *before* the clicking begins. Write any necessary corrections to your walking plan here.

4. (Just a question, not an experiment) Consider this graph of position vs. time for a crazed weasel. At what time is the weasel...



- (a) moving fastest? Explain.

- (b) farthest from his initial position? Explain.

- (c)\* What is the weasel's average velocity between  $t = 0$  and  $t = 15$  s? Explain.

## II. Basic velocity graphs

So far you have plotted your distance (position) from the detector as a function of time. You can also plot how fast you're moving. How fast you move is your speed. It is the rate of change of distance with respect to time. Unlike "speed," the concept of *velocity* takes into account your direction of motion. It can be positive or negative. (Does this distinction help with question 4c?)

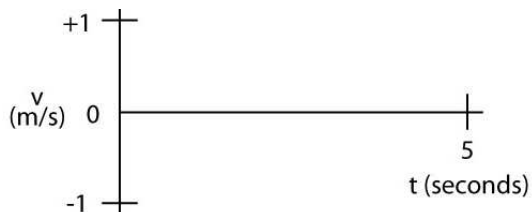
- ♦ Open the file "Kinematics Lab 1B." This will display the velocity graph for your motion.

With this equipment, these velocity graphs come out "rougher" than position graphs do. That's because, even when you're trying to walk steadily, your speed fluctuates up and down a little. When sketching results, smooth out these small fluctuations, to capture the general trend of the graph.

- ♦ Make a velocity graph by walking *away* from the detector *slowly and steadily*. It works best if you begin walking *before* the detector starts clicking. Sketch your result here. (**Remember to draw smooth patterns; leave out the small bumps that are mostly due to your steps.**)

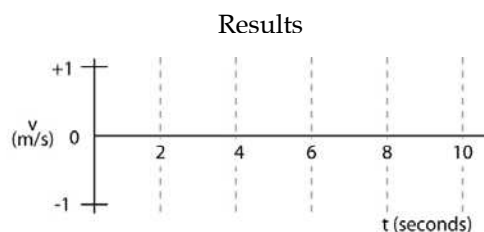
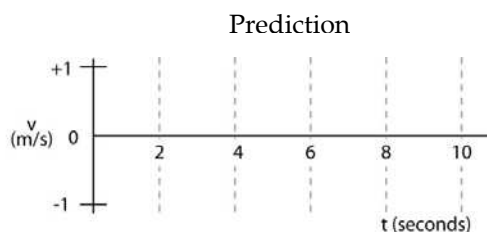


- ♦ Make a velocity graph, walking *towards* the detector *medium fast and steadily*. Again, it helps if you begin walking before the detector starts clicking. Sketch your graph.



- Predict what the velocity vs. time graph will look like when you
  - walk away from the detector medium fast for about 4 seconds, then
  - stop for about 3 seconds, then
  - walk toward the detector, about half as quickly as you walked away from it.

Before running the experiment, sketch your prediction here.



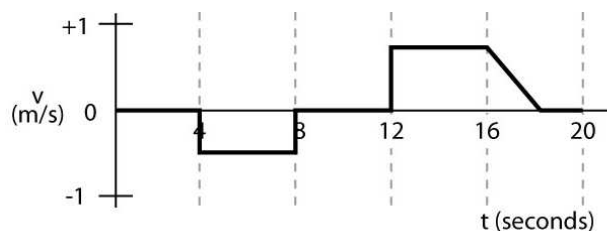
- ♦ Do the experiment a few times, if necessary, to get a clean run.

### Comment

Velocity implies both speed and *direction*. For one-dimensional motion along a straight line, the sign (+ or -) of the velocity indicates the direction. If you move away from the detector (origin), your velocity is positive, and if you move toward the detector, your velocity is negative.

The faster you move *away* from the origin, the larger-positive-number your velocity is. The faster you move *toward* the origin, the larger-negative-number your velocity is.

6. How can you walk to create this velocity vs. time graph?



- (a) Write your “walking plan” here.

- ♦ Before doing the experiment, go to the “Experiment menu” and choose “Extend Collection (15 s).” Then choose it again, “Extend Collection (22.5 s).”
- ♦ Try out your walking plan! Indicate any corrections you had to make to your plan.
- ♦ When doing the experiment, work as a team, and let everyone take a turn walking. Don’t worry if your graph goes a little “higher” or “lower” than it’s supposed to.

- (b) Between  $t = 16$  s and  $t = 18$  s, are you walking in the positive direction (away from the detector) or the negative direction (towards the detector)? Explain.

- (c)\* On a  $v$  vs.  $t$  graph, is it *impossible* to make a perfectly vertical segment, or is it simply very *difficult*? Explain. (Hint: A vertical segment does *not* correspond to going infinitely fast. It instead indicates something more subtle.)



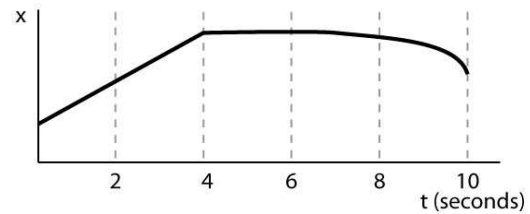
### III. Distance and velocity graphs

In the remaining questions, you'll explore the relationship between distance vs. time and velocity vs. time graphs.

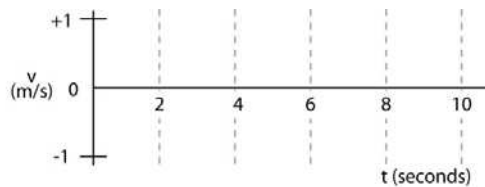
- ♦ Open the file "Kinematics Lab 1C."

7. Study the distance graph shown here, and predict the velocity graph that would result from the motion. Sketch your *prediction* below.

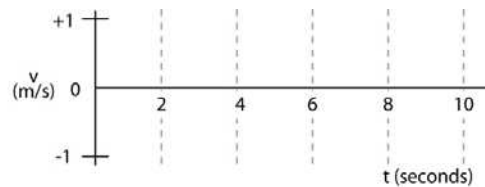
- ♦ Then, walk so as to reproduce this position graph. Do it a few times, to generate a smooth graph. Sketch the corresponding velocity graph *result* below.



Prediction

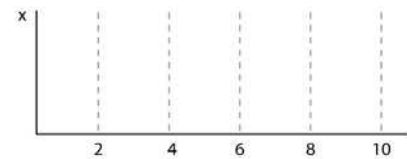


Results

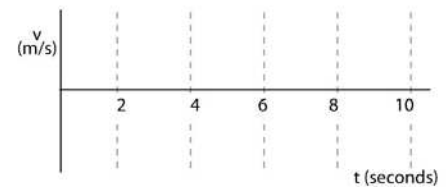


8. In question 7, if you had walked half as fast for the first four seconds:

- (a) How would the position vs. time graph have differed? Sketch it here, and say in words what's different.

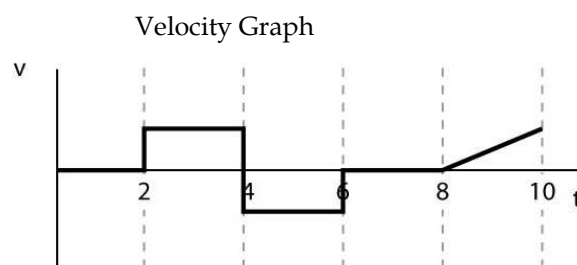


- (b) How would the velocity vs. time graph have differed? Sketch it here, and say in words what's different.

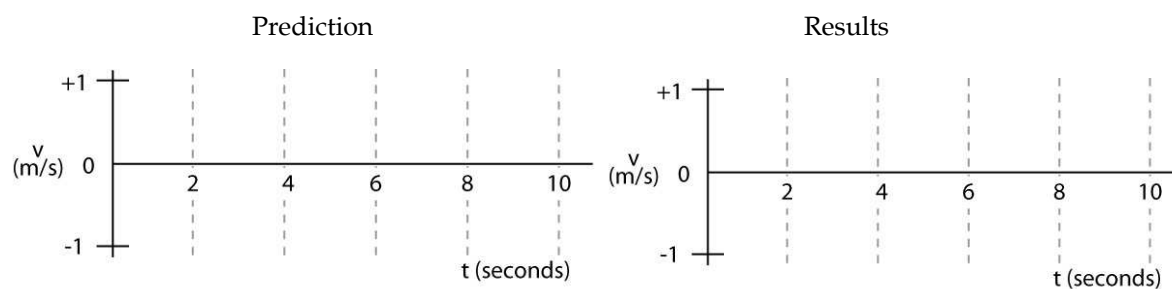




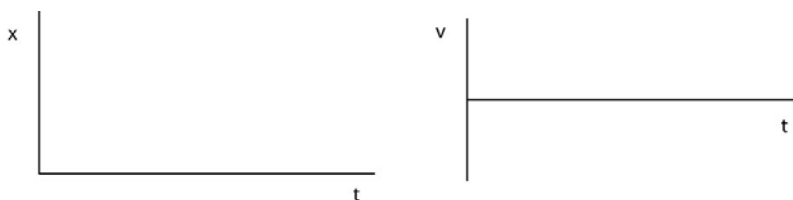
9. Study the **velocity** graph drawn here. What does the corresponding position graph look like? Sketch your prediction below. Consider where the graph should be straight, where it should be curved, and how far the object has traveled.



- ♦ Then, do the experiment. Sketch your result below.



- 10.\* When you walk *toward* the detector while *slowing down*, what do the position and velocity graphs look like? Sketch your predictions here.



- ♦ Do the experiment. If the results differ from your predictions, sketch the results on the above axes (using a dashed line or a different color), and explain why the graphs came out that way.

#### IV. Reaction time

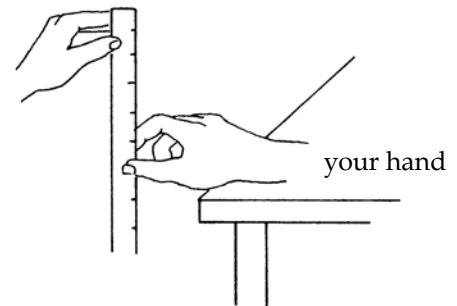
For something different at the end of this lab, we're going to do a rough measurement of your "reaction time." This is the amount of time that passes between when your eyes see something, and when the rest of you reacts. For instance, if you were driving, this could be the amount of time that passes between when you see an obstacle on the road and when your foot hits the brake.

11. Before you try this exercise, what would you guess your reaction time to be? A rough guess is fine: 1 s? 0.1 s? 0.01s? 0.001 s?

Guessed reaction time:

- ♦ Have your partner hold a ruler vertically so that the lower part is between your index finger and thumb as shown. Note the ruler mark near where your fingers are. **Your thumb and index finger should be separated by about 1 cm.** When your partner lets go without warning, close your fingers on the ruler as quickly as possible. After you have grabbed the ruler, note now where your fingers are, and record the distance that the ruler has fallen. Do this several times.

partner holds ruler



Distance ( $\Delta y$ ) values:

- ♦ Compute the average value of your trials. (Please remember to keep only a reasonable number of digits when computing the average!)

Average distance,  $\Delta y_{\text{avg}}$ :

You will learn next week that a body falling under the influence of gravity travels a distance  $\Delta y$  in time  $\Delta t$

$$\Delta y = \frac{1}{2} g(\Delta t)^2, \text{ where } g \approx 10 \text{ m/s}^2.$$

12. What was your approximate reaction time? Show your calculation and result here. [Reminder: 1 cm = 0.01 m]

Approximate reaction time ( $\Delta t_{\text{react}}$ ):

How does your measured reaction time compare to what you were expecting?

13. If you were driving down the highway at 60 mi/hr ( $\approx 100$  km/hr), approximately how far would you travel before you hit the brakes after spotting an obstacle ahead?

For a more physical context, put this “reaction time distance” in terms of something easily seen: the length of this page, the length of a lab table, the length of this room, the length of the building, etc.

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**For later...**

If you'd like to try something similar to the above with a friend: Ask your friend for a dollar bill, and hold the bill vertically so that the center (George Washington's face) is between your friend's fingers. Then challenge him or her to catch the bill as quickly as possible after you suddenly release it. If you can make a bet that it'll hit the floor, you'll probably win the buck. Can you calculate why? (Most people's reaction time at best is about 0.2 s.)

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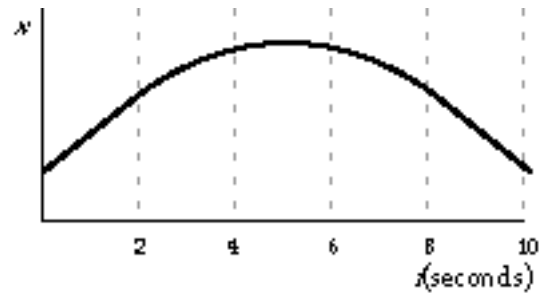
**Credit and information**

The computer activities of this and next week's labs were adopted from the “Tools for Scientific Thinking” series of activities, developed by the Center for Math, Science, and Technology at Tufts University.

## KINEMATICS LAB 1: Extra questions

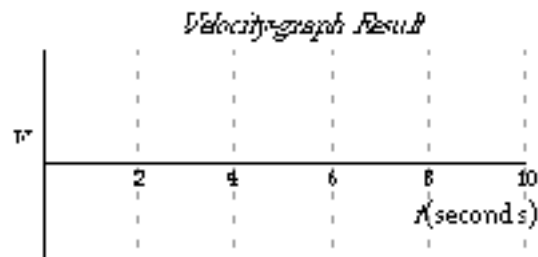
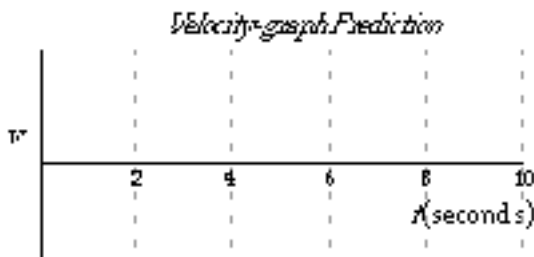
**Note:** These extra questions, intended for people who finish the main lab early, give you practice applying the same concepts to harder situations. These questions are strictly for your benefit; they will not count as part of your lab grade, and they do not cover new material. But they are designed to give you practice on exam-level questions.

1. Consider this *position* vs. time graph. What does the corresponding velocity vs. time graph look like?

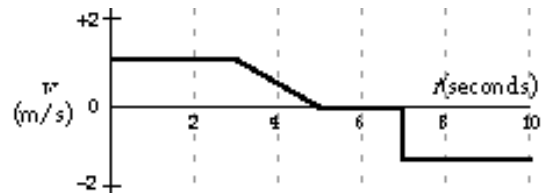


- (a) Sketch your prediction below.

- ♦ Now reproduce the position graph by walking, and see if the velocity graph comes out the way you expect.

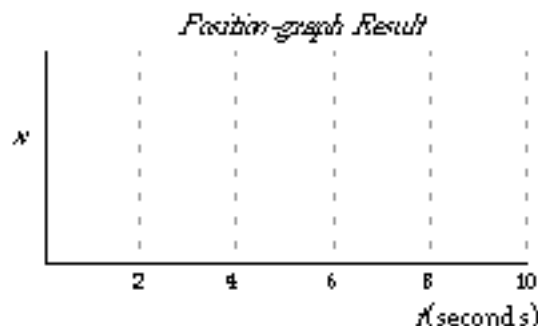
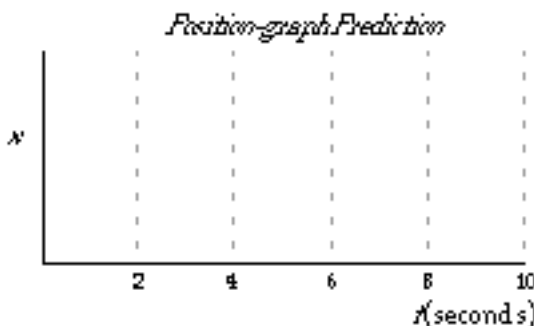


2. Here's a *velocity* vs. time graph. What does the corresponding position graph look like?

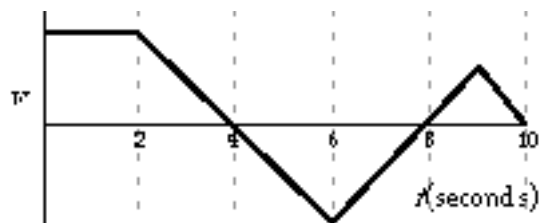


- (a) Sketch your prediction below.

- ♦ Now reproduce the velocity graph by walking, and see if the position graph comes out the way you expect.



3. Consider this velocity vs. time graph.



(a)\* At what times does the object change direction? How do you know?

(b)\* What is the object doing at  $t = 6$  s and  $t = 9$  s. (Hint: It's *not* changing direction.)

(c) In which direction is the object moving at  $t = 7$  s? Explain.

(d)\* At what time is the object farthest from its initial position? How do you know?

(e)\*\* How would you walk to create this motion? (If you have time, try it!)