Name: ______________________________
Partners: ______________________________
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PHYSICS 220 LAB #1: ONE-DIMENSIONAL MOTION

Bats navigate in the dark with spectacular speed and agility by emitting a series of supersonic calls, which echo back and warn them of obstacles. When interfaced to a laboratory computer, a detector based on the same principle can help you track your motion along a line and begin to learn about how different types of motion are described.

(Equipment: Track, Motion Detector, LabPro, Computer, Fan Cart, Fan Cart Sail)

OBJECTIVES

1. To learn about three complementary ways to describe motion in one dimension—words, graphs, and vector diagrams.
2. To acquire an intuitive understanding of speed, velocity, and acceleration in one dimension.
3. To recognize the patterns of position vs. time, velocity vs. time, and acceleration vs. time for the motion of objects which speed up or slow down at a constant rate and to recognize this type of motion as constantly accelerated motion.

OVERVIEW

You will begin your studies of motion using an ultrasonic motion detector attached to a microcomputer, to study the motion of your own body as well as that of a cart that increases and decreases its velocity at a steady rate. The rules for calculating velocity and acceleration from distance and time measurements are programmed into the motion software, so you can get a feel for what velocity and acceleration mean and how they are represented graphically.

The ultrasonic motion detector sends out a series of sound pulses that are too high frequency for you to hear. These pulses reflect from objects in the vicinity of the motion detector and some of the sound returns to the detector.

The computer is able to record the time it takes for reflected sound waves to return to the detector and then, by knowing the speed of sound in air, figure out how far away the reflecting object is. There are several things to watch out for when using a motion detector:

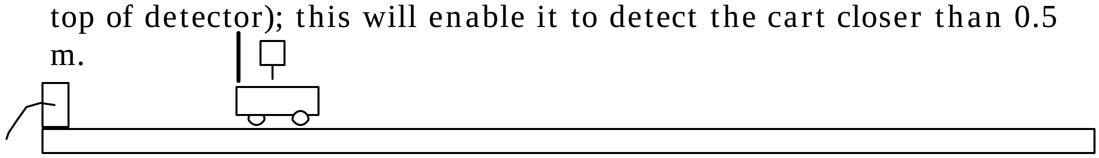
1. Do not get the cart much closer than 0.1 meters from the detector because it cannot record reflected pulses that come back too soon.
2. The ultrasonic waves come out in a cone of about 15°. It will see the closest object (including your hands if they're in the way). Be sure there is a clear path between the object whose motion you want to track and the motion detector.
3. The motion detector is very sensitive and will detect slight motions. You should try to move smoothly, but don't be surprised to see small bumps in velocity graphs and larger ones in acceleration graphs.

PRE-LAB (to be completed before coming to lab)

Prior to coming to lab, read through this write-up and perform all the exercises labeled "**Pre-Lab**". You will also want to copy this work onto the back pages of the lab, which I will collect during the first 5 minutes of lab as a check that you actually did it *pre* - lab. However, during the course of the lab, you may find that a pre-lab is incorrect – correct it in you lab hand-out; I will grade that (provided you initially did respectably).

PART ONE: Position vs. Time

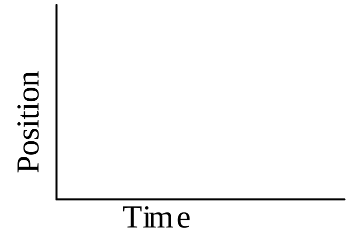
1. Make sure a LabPro interface box is connected to your computer, and has a motion detector plugged into the port labeled DIG/SONIC 1. Open **"Distance"** (in Physics Experiments/Physics 220-221/One-Dimensional Motion). You'll move a cart along a track, in front of a motion detector.
2. Place the motion detector at the end of a level track as shown below. Switch the detector to its narrower sensor range (switch on top of detector); this will enable it to detect the cart closer than 0.5 m.



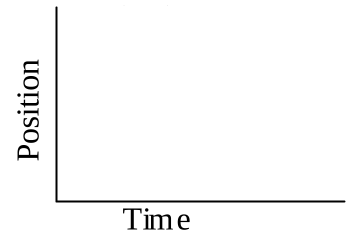
3. **Pre-Lab** With a dashed line, sketch what you expect in the plots of 3 a, b, and c.
4. Make position-vs.-time graphs for different cart speeds and directions by clicking on the "Collect" button at the bottom of the screen and moving the cart in front of the motion detector at distances that are no closer than 0.1 m. **Note**: to get the smoothest graphs, a) put a 'sail' on the cart so it faces the detector (and acts as a nice flat target for it to detect) and b) start your motion just

before the detector starts collecting and stop your motion just after it stops collecting. Try the following motions and sketch the graph you observe in each case:

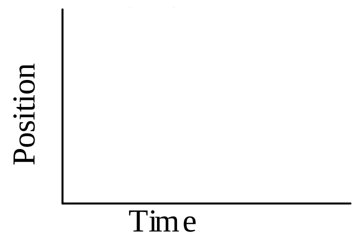
(a) Starting 0.1 m from the origin (i.e. the detector), move the cart away *slowly and steadily*.



(b) Starting 0.1 m from the origin, move the cart away from the origin *medium fast and steadily*.



(c) Starting 1.0 m from the origin, move the cart toward the detector *slowly and steadily*. Sketch the graph.



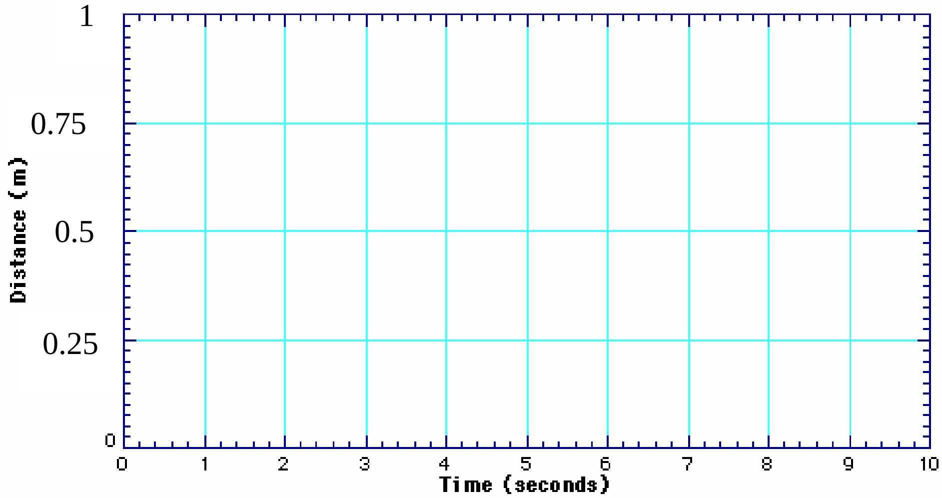
Pre-Lab: What do you expect to be the difference between the graph you'll make by moving away slowly and the one made by moving away more quickly?

Question: Were you correct? If not, what was the difference between the two graphs?

Pre-Lab: What is the difference between the graph made by moving toward and the one made moving away from the motion detector?

Question: Were you correct? If not, what was the difference between the two graphs?

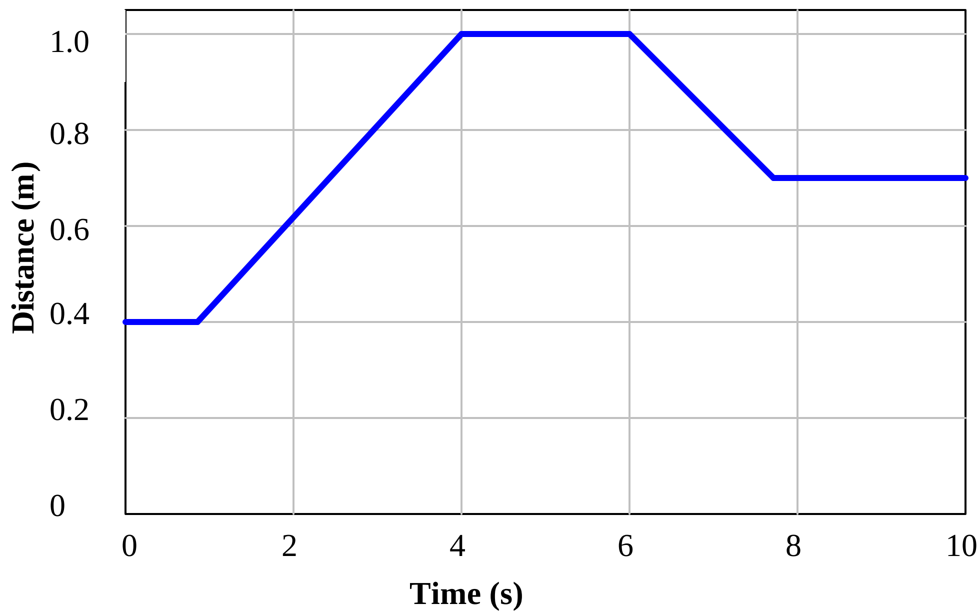
5. **Pre-Lab**: A good way to double check that you understand how to interpret position-vs.-time graphs is to predict the shape of a graph that would result for a motion described in words and then carry out the motion. Sketch your prediction for the following sequence on the axes below using a *dashed* line. Suppose your cart were to start 0.1 m in front of the detector and move away slowly and steadily for 4 seconds, stops for 4 seconds, and then move toward the detector quickly.



6. After making your prediction, click on the "Collect" button and move in the way described above. Sketch the actual graph of your actual motion with a *solid* line.

Question: Is your prediction the same as the final result? If not, describe how you would move to make a graph that looks like your prediction?

7. Pull down the *File* menu and select *Open*, then select the experiment file called **"Position Match"** (in Desktop / Physics Experiments / Physics 220 – 221/ One-Dimensional Motion). A position graph like that shown below should appear on the screen.



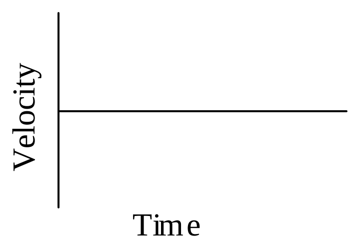
Pre-Lab: Describe in your own words how you would move the cart in order to match this graph.

8. Click the "Collect" button and move to match the graph on the computer screen. Repeat this until you get the times and positions right. It helps to work in a team.

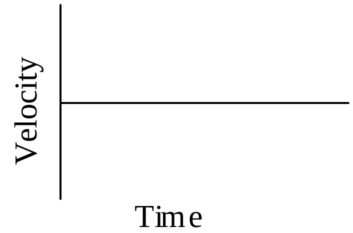
PART TWO: Velocity vs. Time

1. **Pre-Lab** With a dashed line, sketch what you expect in the plots of 2 a, b, and c.
2. Next, you will make some velocity-vs.-time graphs of your motion. Pull down the *Data* menu and select *Clear All Data*, then click on the axis label "Position" and when the Y-Axis Selection box comes up select "Velocity." Try the following motions and sketch the graph you observe in each case:

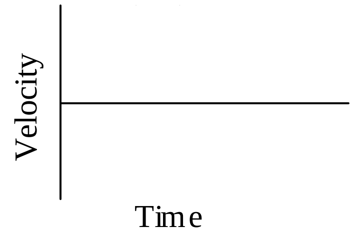
(a) Starting 0.1 m from the origin (i.e. the detector), move the cart away *slowly and steadily*.



(b) Starting 0.1 m from the origin, move the cart away from the origin *medium fast and steadily*.



(c) Starting 1.0 m from the origin, move the cart toward the detector *slowly and steadily*. Sketch the graph.

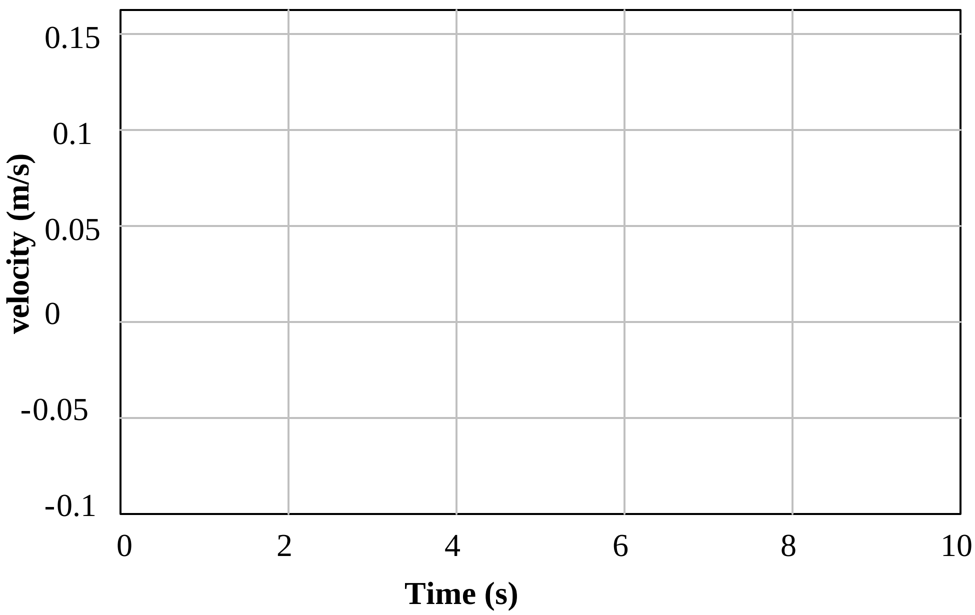


Pre-Lab: What do you expect to be the most important difference between the graph made by *slowly* moving away from the detector and the one made by moving away *more quickly*?

Question: Were you correct? If not, what was the most important difference?

Pre-Lab: How should the velocity-vs.-time graphs be different for motion *away* and motion *toward* the detector?

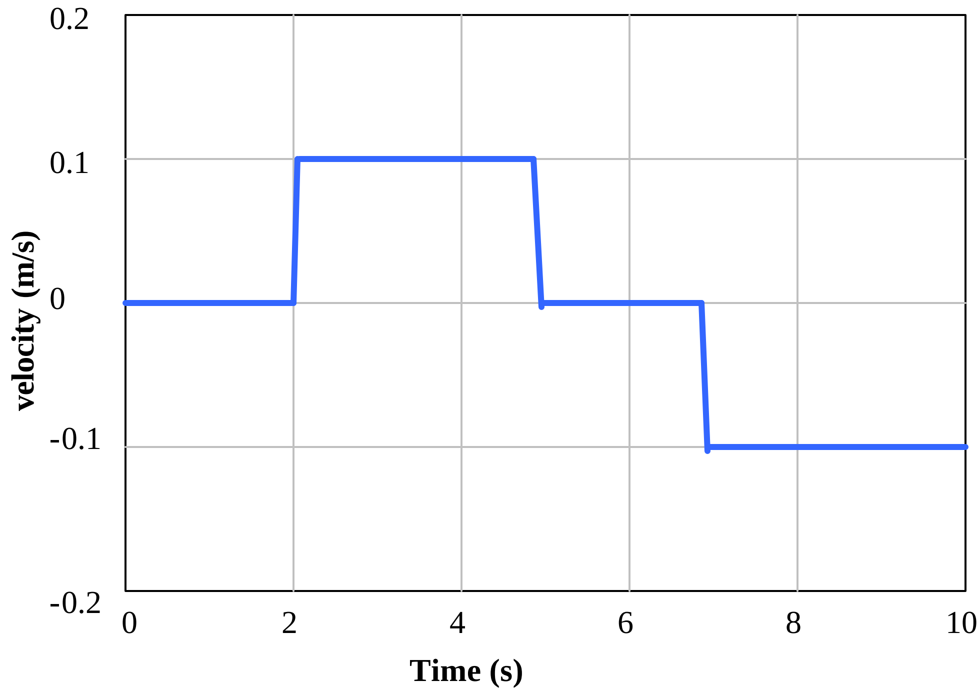
3. **Pre-Lab:** Suppose your cart were to undergo the following sequence of motions: move away from the detector slowly and steadily for 4 seconds; stand still for 4 seconds; move toward the detector steadily about twice as fast as before. Sketch your prediction of the velocity-vs.-time graph on the axes below using a *dashed* line.



4. After making your prediction, repeat your motion until you are confident that it matches the description in words. Draw the actual graph on the axes above using a *solid* line.

Question: Is your prediction the same as the final result? If not, describe how you would move to make a graph that looks like your prediction?

5. Open the file **Velocity Match**, (in Physics Experiments / Physics 220 – 221/ One-Dimensional Motion). A velocity graph like that shown below should appear on the screen.



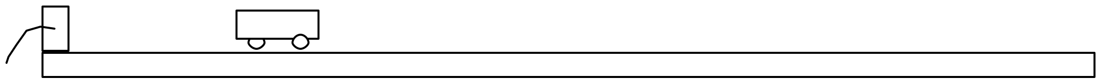
Pre-Lab: Describe in your own words how you would move the cart in order to match this velocity graph.

6. Try to move the cart in such a way that you can reproduce the graph shown. You may have to practice a number of times to get the movements right. Work as a team and plan your movements. Get the times right. Get the velocities right. Then draw in your group's best match on the axes above.

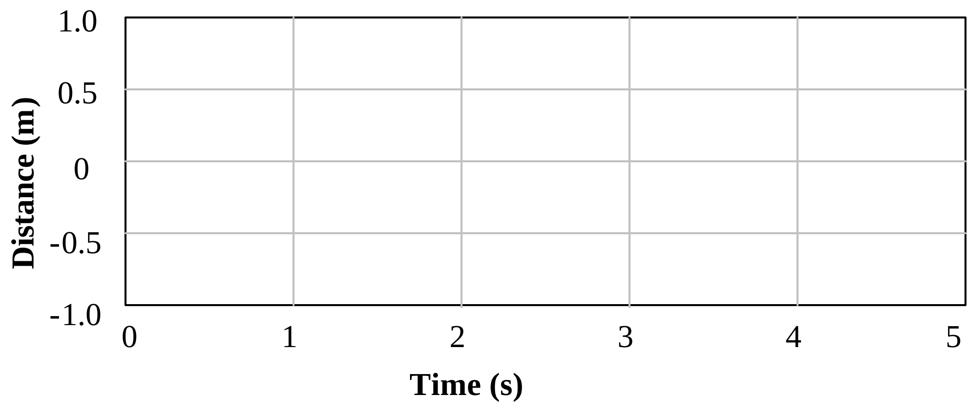
Question: Is it possible for an object to move so that it produces an absolutely vertical line on a velocity-vs.-time graph? Explain.

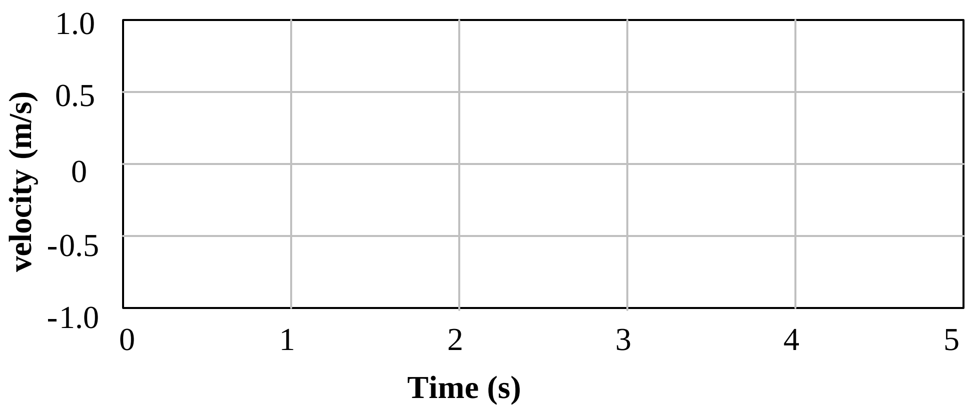
PART THREE: Acceleration vs. Time

1. Next, you will see how acceleration graphs are related to position and velocity graphs. Open **Cart** (in Physics Experiments/ Physics 220-221/ One-Dimensional Motion).

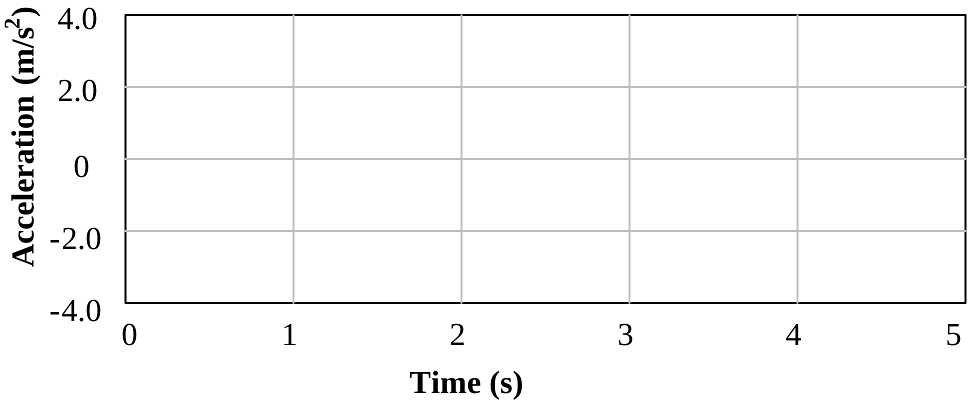


2. Put a cart on the track, click on the "Collect" button, and give it a good push (so it takes about 1 sec to go down the track). Record the resulting graphs below. Note: we're particularly interested in the motion *after* you've stopped pushing and *before* you catch the cart at the other end. **Note:** when drawing the plots below, pay special attention to the timing.



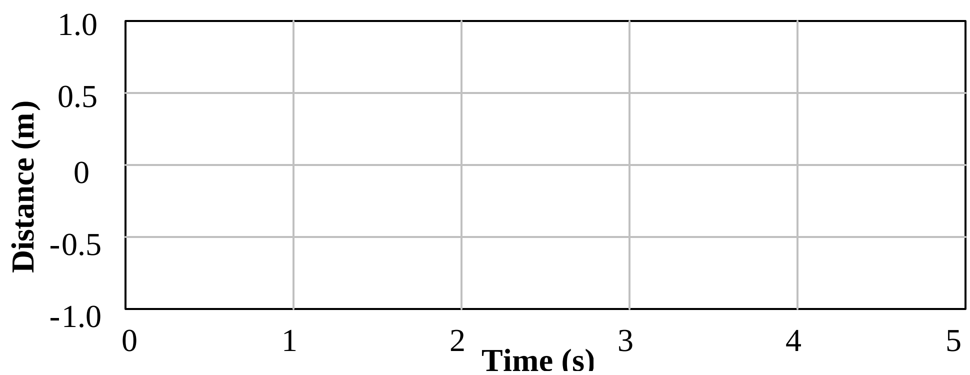


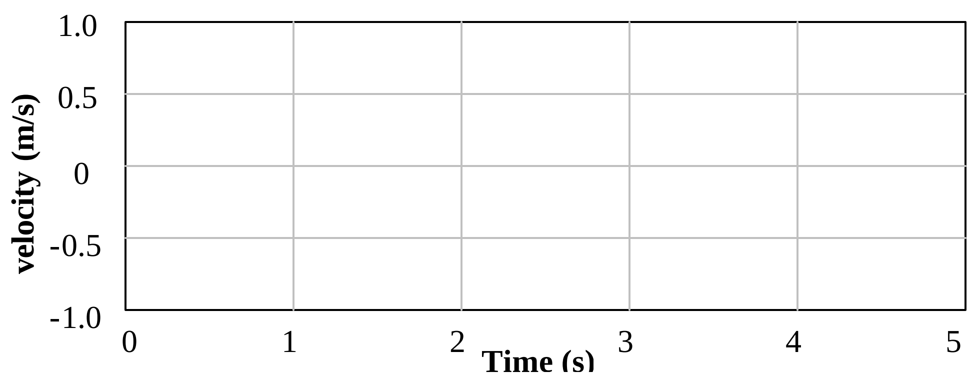
3. Sketch your prediction of the cart's acceleration (for the motion you just observed) on the axes that follow using a *dashed* line.

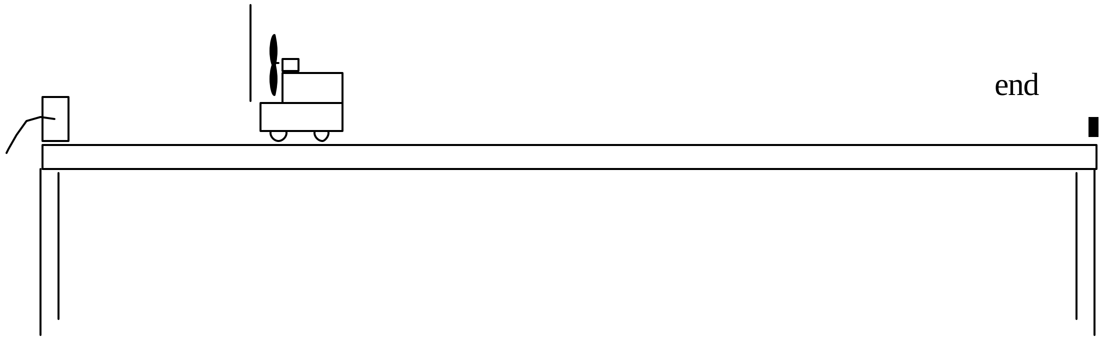


4. <u>After</u> making your prediction, display the acceleration graph of the cart by switching either the "Distance" or "Velocity" axis label to "Acceleration." Sketch it on the axes above using a <u>*solid* line</u>.

5. Set the second graph to display the velocity. Release a fan-powered cart with the fan set to "low" so that it moves away from the detector. If need be, you can rotate the fan to further slow the cart. **Always catch the cart before it crashes at the end!** Sketch the resulting graphs neatly on the following axes.

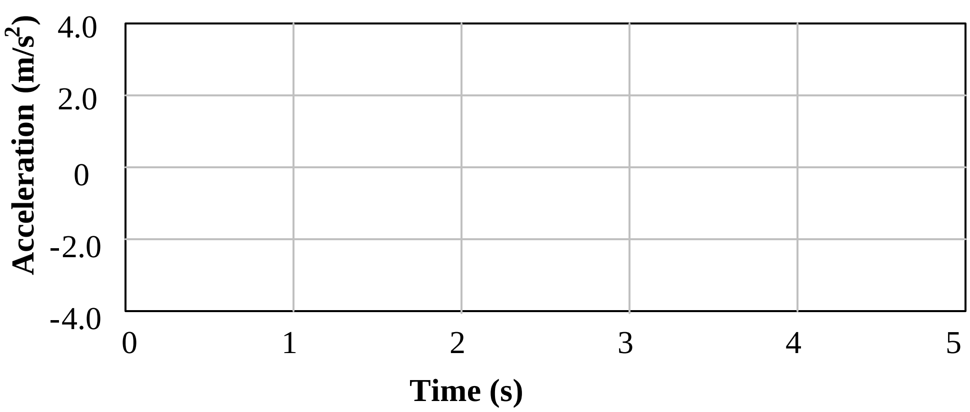






Question: How do your graphs differ from the previous motion?

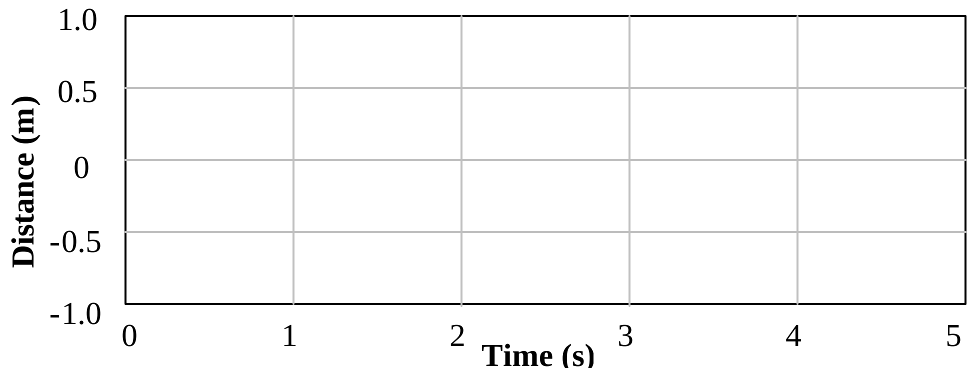
6. Sketch your prediction of the fan-powered cart's acceleration on the axes that follow using a ***dashed* line**.

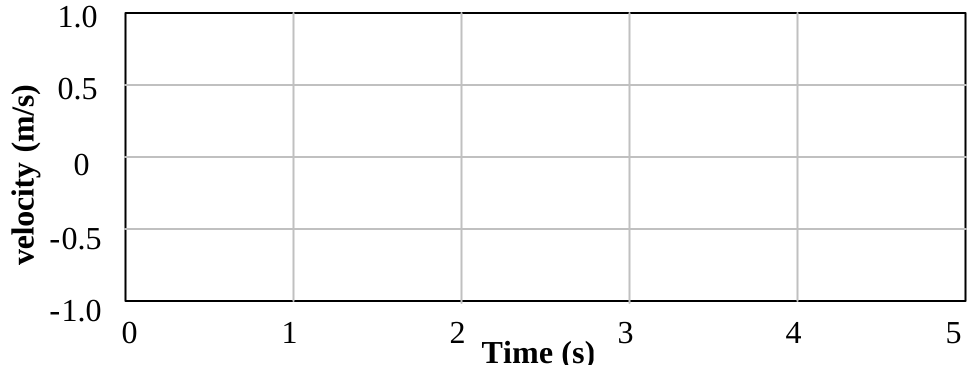


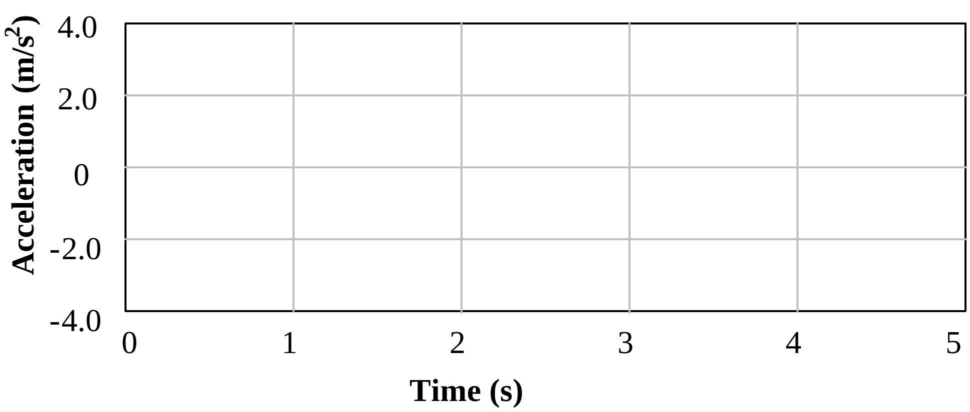
7. After making your prediction, display the acceleration graph. Sketch it on the axes above using a *solid* line.

Question: How does the acceleration vary in time (or does it?) as the cart speeds up? How could you predict this based on the velocity graph?

8. Sketch your predictions of how the graphs will look if the fan is set to “high” on the axes that follow using a <u>*dashed* line</u>.



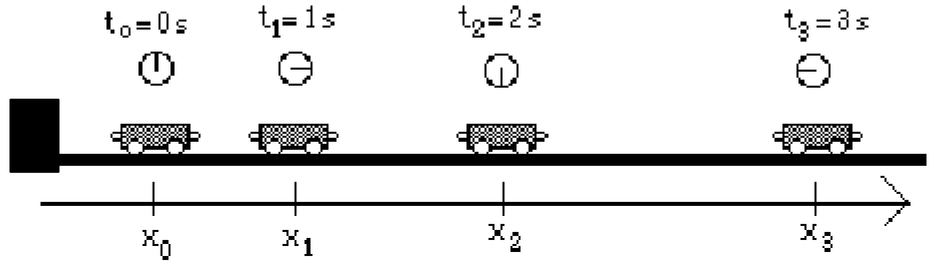




9. <u>After</u> making your predictions, test them by accelerating the cart with the fan set on “high” and draw the results on the axes above using a <u>*solid* line</u>.

Question: Did the general shapes of your velocity and acceleration graphs agree with your predictions? How is the greater magnitude (size) of acceleration represented on a velocity-vs.-time graph?

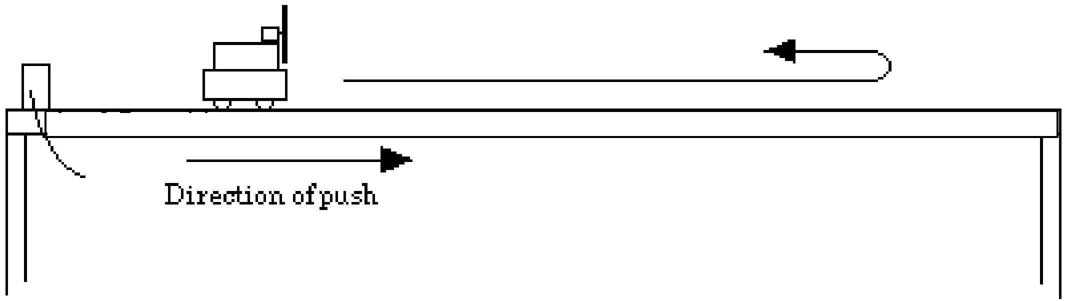
10. **Pre-Lab**: The diagram that follows shows the positions of the cart at equal time intervals. (This is like taking snapshots of the cart at equal time intervals.) At each indicated time, sketch a vector (i.e., representative arrow) above the cart which **might** represent the velocity of the cart at that time while it is moving away from the motion detector (to the right) and speeding up. Label the velocity vectors $\vec{v}_0, \vec{v}_1, \vec{v}_2, \ldots$



11. **Pre-Lab**: Use graphical vector subtraction (like in Ch. 1, with nothing but arrows) to find the approximate length and direction of the vector representing the change in velocity between the times 1.0 s and 2.0 s using the diagram above. No numerical calculations are needed.

Question: Does the direction of the change in the velocity agree with the sign of the acceleration measured in step 9? Explain.

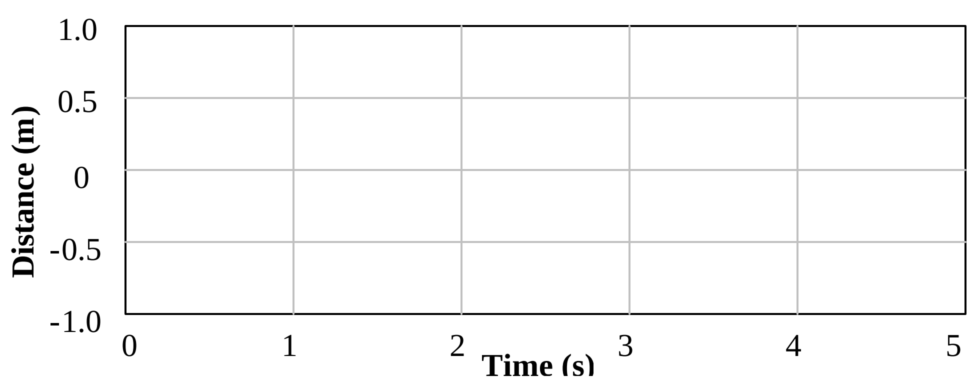
12. Set the fan to “low” and turn the cart around so that it would be blown toward the detector if released. Practice giving the cart a push *away* from the motion detector. It should move toward the end of the ramp, slows down, reverses direction and then moves back toward the detector. **Be sure to stop the cart before it hits the motion detector!**

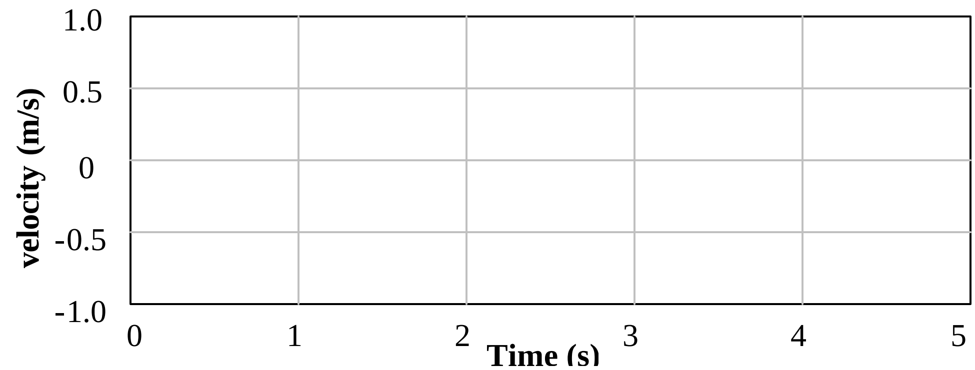


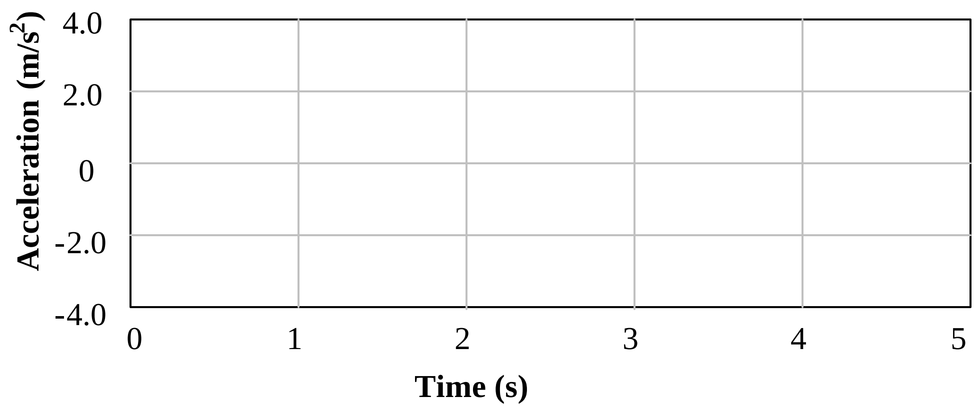
13. **Pre-Lab**: For each part of the motion after you release the cart—*away from the detector, at the turning point, and toward the detector*—predict in the table that follows whether the velocity and acceleration will be positive, zero or negative.

	Moving Away	Turning Around	Moving Toward
Velocity			
Acceleration			

14. Collect data for this motion and sketch the graphs on the next page. Label the times: “A” - where the push ended (where your hand left the cart), “B” - where the cart reversed direction, and “C” - where you stopped the cart.







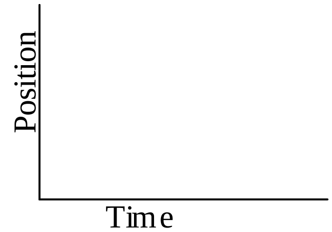
15. Put an "X" through any of your predictions in step 13 that were wrong and correct them.

Question: Draw a motion diagram and use it to explain the direction (sign) of the acceleration at the point where the cart turns around. (Ex. figures 2.8 and 2.9 in the text are 'motion diagrams').

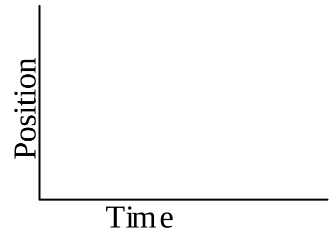
Pre-Lab #1 **Name:___________________**

Pre-Lab 1 With a dashed line, sketch what you expect in the plots below.

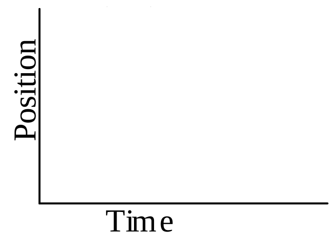
(a) Starting 0.1 m from the origin (i.e. the detector), move away *slowly and steadily*.



(b) Starting 0.1 m from the origin, move away from the origin *medium fast and steadily*.



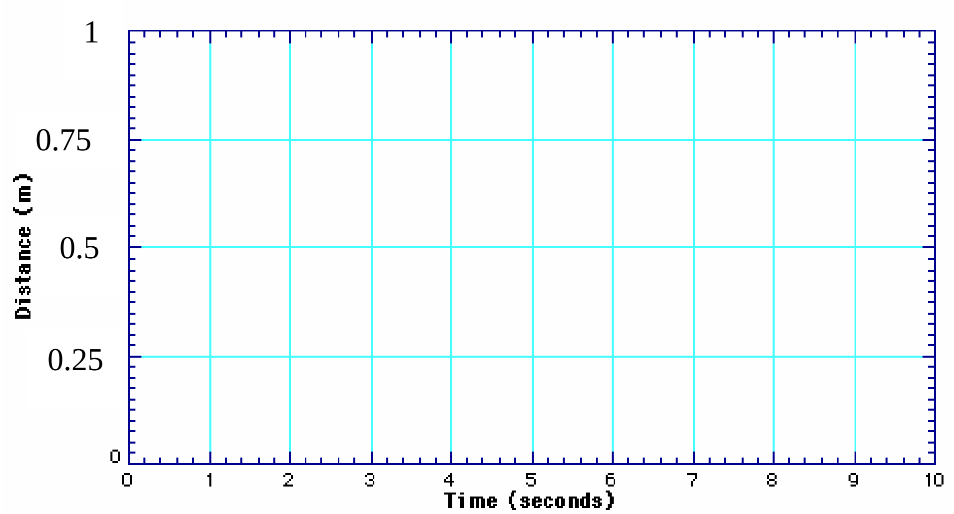
(c) Starting 1.0 m from the origin, move toward the detector *slowly and steadily*. Sketch the graph.

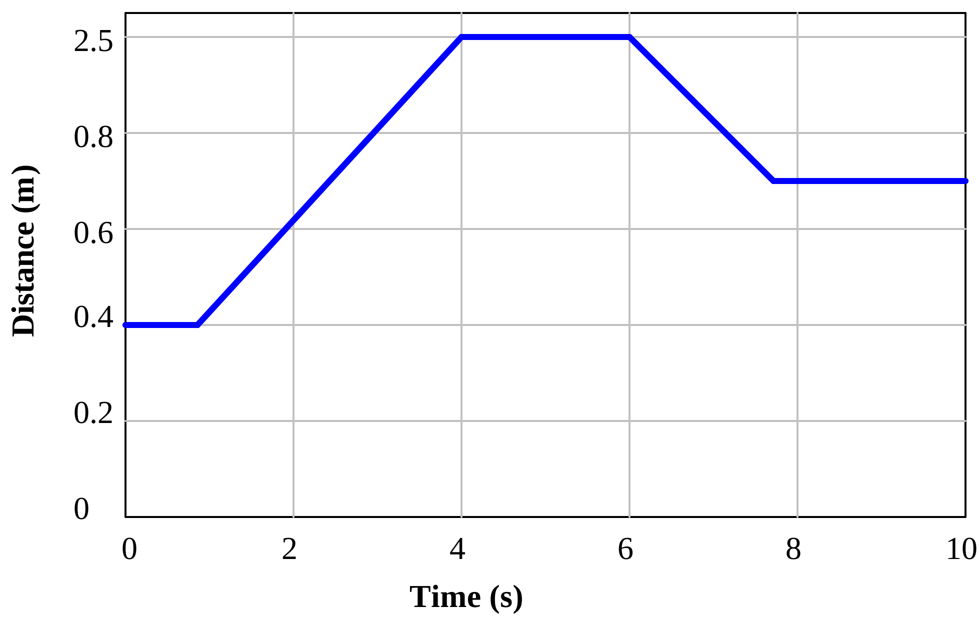


Pre-Lab: What do you expect to be the difference between the graph you'll make by moving away slowly and the one made by moving away more quickly?

Pre-Lab: What is the difference between the graph made by moving toward and the one made walking away from the motion detector?

Pre-Lab: A good way to double check that you understand how to interpret position-vs.-time graphs is to predict the shape of a graph that would result for a motion described in words and then carry out the motion. Sketch your prediction for the following sequence on the axes below using a *dashed* line. Suppose your were to start 0.1 m in front of the detector and move away slowly and steadily for 4 seconds, stops for 4 seconds, and then move toward the detector quickly.

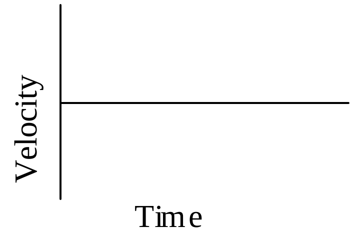




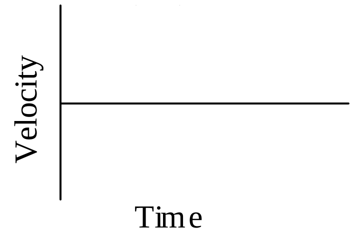
Pre-Lab: Describe in your own words how you would move a cart in order to match this graph.

Pre-Lab With a dashed line, sketch what you expect in the following plots.

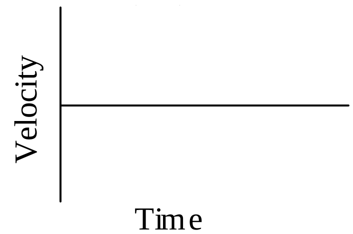
(a) Starting 0.1 m from the origin (i.e. the detector), move away *slowly and steadily*.



(b) Starting 0.1 m from the origin, move away from the origin *medium fast and steadily*.



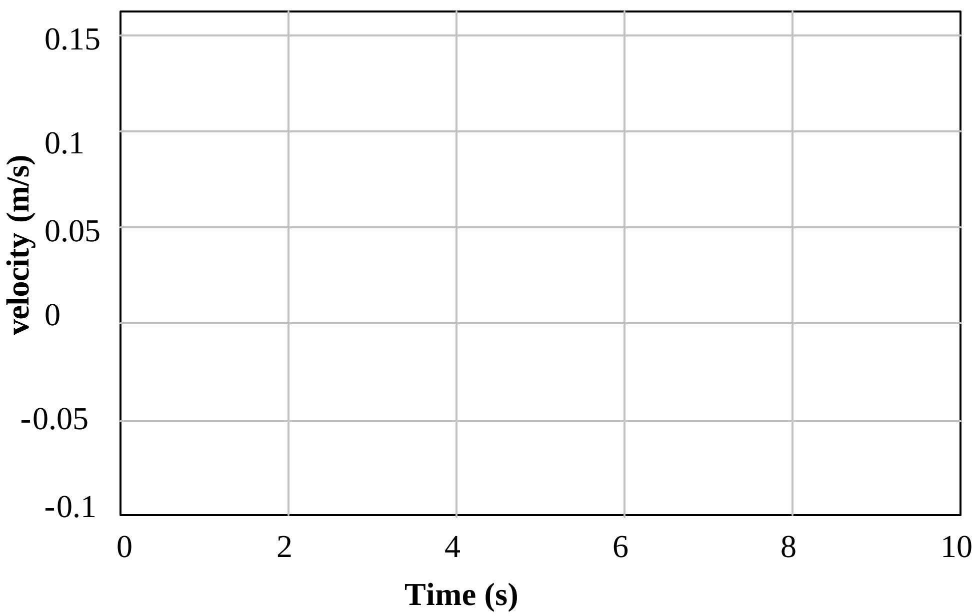
(c) Starting 1.0 m from the origin, move toward the detector *slowly and steadily*. Sketch the graph.

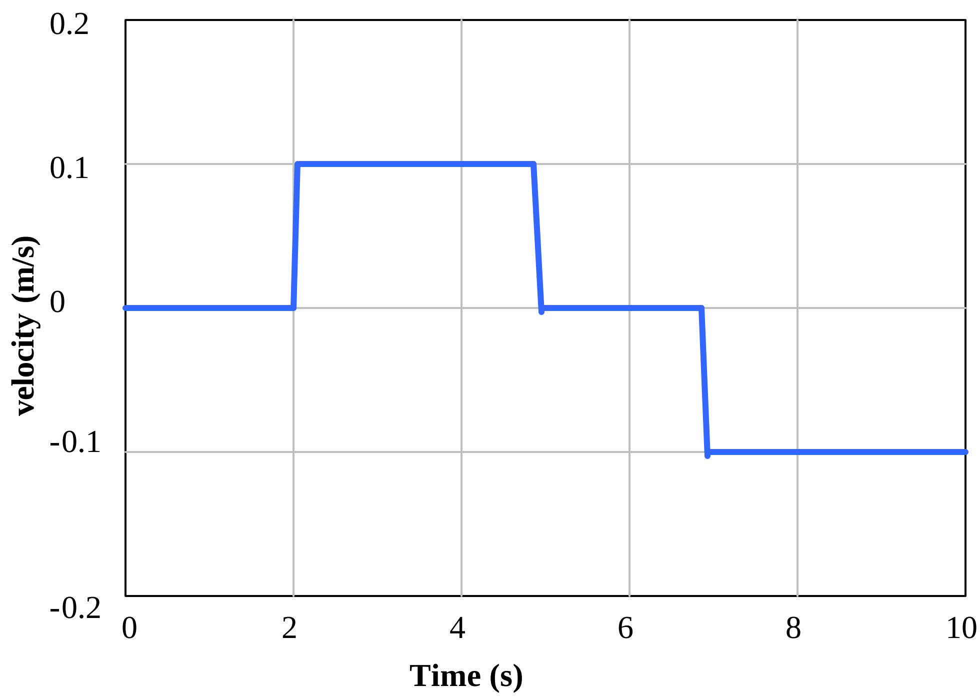


Pre-Lab: What do you expect to be the most important difference between the graph made by *slowly* moving away from the detector and the one made by moving away *more quickly*?

Pre-Lab: How should the velocity-vs.-time graphs be different for motion *away* and motion *toward* the detector?

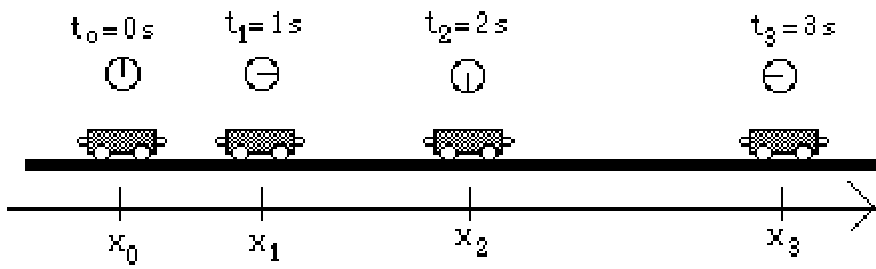
Pre-Lab: Suppose you were to undergo the following sequence of motions: move away from the detector slowly and steadily for 4 seconds; stand still for 4 seconds; move toward the detector steadily about twice as fast as before. Sketch your prediction of the velocity-vs.-time graph on the axes below using a *dashed* line.



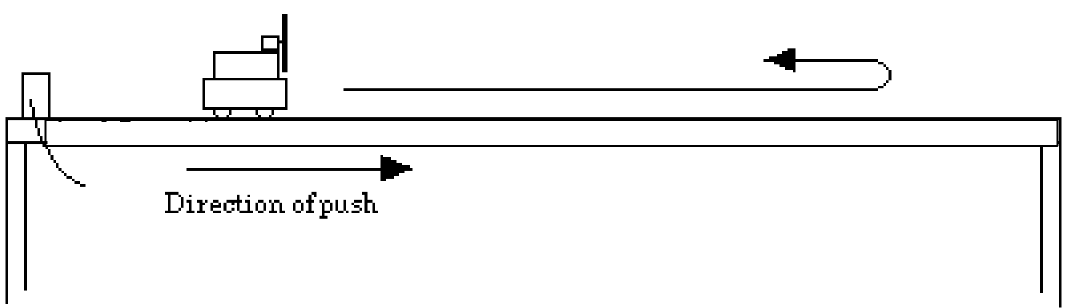


Pre-Lab: Describe in your own words how you would move in order to match this velocity graph.

Pre-Lab: The diagram that follows shows the positions of the cart at equal time intervals. (This is like taking snapshots of the cart at equal time intervals.) At each indicated time, sketch a vector above the cart which **might** represent the velocity of the cart at that time while it is moving away from the motion detector (to the right) and speeding up. Label the velocity vectors $\vec{v}_0, \vec{v}_1, \vec{v}_2, \ldots$



Pre-Lab: Use graphical vector subtraction to find the approximate length and direction of the vector representing the change in velocity between the times 1.0 s and 2.0 s using the diagram above. No numerical calculations are needed.



Pre-Lab: For each part of the motion after you release the cart—*away from the detector, at the turning point, and toward the detector*—predict in the table that follows whether the velocity and acceleration will be positive, zero or negative.

	Moving Away	Turning Around	Moving Toward
Velocity			
Acceleration			