Name______________________________ Date________________

PRE-LAB PREPARATION SHEET FOR LAB 3: CHANGING MOTION

(*Due at the beginning of Lab 3*)

Directions:
Read over Lab 3 and then answer the following questions about the procedures.

1. In Activity 1-1, consider the changes in motion that a cart will undergo when it is attached to a fan. How will the velocity vs. time graphs differ from those you made in Lab 1 for motion with a constant velocity?

2. In Activity 3-1, the cart will initially be slowing down while moving in the positive direction. Will the acceleration be positive, negative or zero during this first portion of its motion?

3. In Activity 3-1, the cart will change direction and its velocity will switch from being positive to negative. Will the acceleration be positive, negative or zero at the instant when it is changing direction?

4. In Activity 3-1, the cart will eventually begin moving in the negative direction and speeding up. Will the acceleration be positive, negative, or zero during this final portion of its motion?

Name______________________________Date_____________Partners________________________

LAB 3:
CHANGING MOTION

OBJECTIVES

- To understand how and when objects accelerate.
- Analyze and interpret kinematics graphs to find out the meaning of acceleration.
- Identify the relationships between distance, velocity, and acceleration graphs.
- Learn to calculate average acceleration from acceleration and velocity graphs.

OVERVIEW

In this lab you will observe and describe various situations where an object's motion is changing. Any time the velocity of an object changes, it is accelerating. Acceleration is the rate of change of velocity with respect to time. In this lab you will look at velocity vs. time and acceleration vs. time graphs of the motion of a cart with a fan attached. The fan will cause the cart to speed up, slow down, or change its direction with a constant acceleration. Creating the velocity vs. time and acceleration vs. time graphs will help us build our intuitive understanding of how objects accelerate.

MATERIALS

- Graphical Analysis application
- Fan unit attachment with batteries and dummy cells
- Go Direct Sensor Cart
- Low friction track
- Adjustable end stop

INVESTIGATION 1: VELOCITY AND ACCELERATION GRAPHS

Activity 1-1: Speeding Up

In this activity you will see how velocity vs. time and acceleration vs. time graphs relate to each other when a cart's speed is increasing. The fan will provide a constant acceleration for the cart.

1. Launch Graphical Analysis. Choose Sensor Data Collection, and make sure the cart is on. Connect the Sensor Cart to your computer. Click to open Data Collection Settings in the lower left-hand corner of the screen. Change End Collection to 3 s, then click Done. If only one graph is displayed, click View, , and choose 2 Graphs. (A graph of position vs. time and velocity vs. time.)

2. Make sure the fan switch is off, then insert **three** batteries and one dummy cell in the battery compartment of the fan unit.

3. Place the cart on one end of the track far from the adjustable end stop. The fan should be attached so that the cart is pushed in the +x direction. Click on the live position readout on the bottom right-hand side and zero the detector. Click Collect to start data collection and release the cart from rest, letting it move with the fan.

4. Examine the position vs. time graph. Repeat Step 3 if your position vs. time graph does not show an area of smoothly changing position. Check with your instructor if you are not sure whether you need to repeat data collection. This data will be automatically saved and used for analysis in Investigation 2.

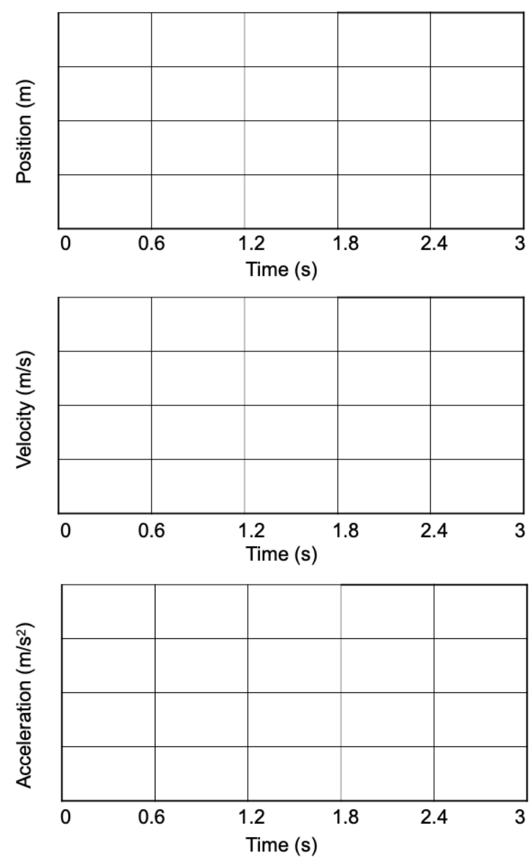
5. Sketch your position and velocity data neatly in the following graphs. Ignore the acceleration axes for now.

Speeding Up

and

Speeding Up More

(prediction & data)



Question 1-1: How does your position graph here differ from a position graph that shows steady (constant velocity) motion?

Question 1-2: How can you tell from your **velocity graph** that the motion was in the positive direction?

Question 1-3: How can you tell from your **velocity graph** that the cart was speeding up? If the cart was moving at a constant speed, how would the velocity graph look different?

6. Press View, ⊞, and change your view to 3 Graphs. The third graph should show the acceleration. Sketch your graph on the acceleration axes on the previous page and label it "speeding up."

7. Make a note of which data set you are sketching. All data sets are automatically saved, and you will use this data set for analysis in Investigation 2.

Data Set __________

Question 1-4: While the cart is speeding up in the positive direction, is the acceleration positive or negative? Describe how can we tell the sign of the acceleration from the graph as the cart speeds up while moving away from the detector?

Question 1-5: How does the velocity change with respect to time as the cart speeds up? Does it increase at a constant rate, or change in some other way?

Question 1-6: How does the acceleration change with respect to time as the cart speeds up? Is this what you expected based on the velocity graph? Explain your answer.

Activity 1-2: Speeding Up More

Prediction 1-1: If you accelerated the cart with a stronger fan, what would be different about your velocity and acceleration graphs? Answer here **and** sketch your predictions with a dashed line or different colors on the previous set of graphs.

8. Test your prediction by making the velocity and acceleration graphs. Repeat the experiment, but this time accelerate the cart with all four batteries in the battery compartment. (Only turn the fan on when making measurements.) If necessary, repeat the measurement to get nice graphs. This data will be automatically saved and used for analysis in Investigation 2, record which data set you will use.

Data Set _________

9. Sketch your velocity and acceleration graphs with solid or different color lines on the previous set of axes or **print** them together, showing only the two data sets from Steps 6 and 8. Label this latest graph "Speeding Up More."

Question 1-7: Did the shapes of your velocity and acceleration graphs agree with your predictions? How can you tell the magnitude of the cart's acceleration from a velocity vs. time graph?

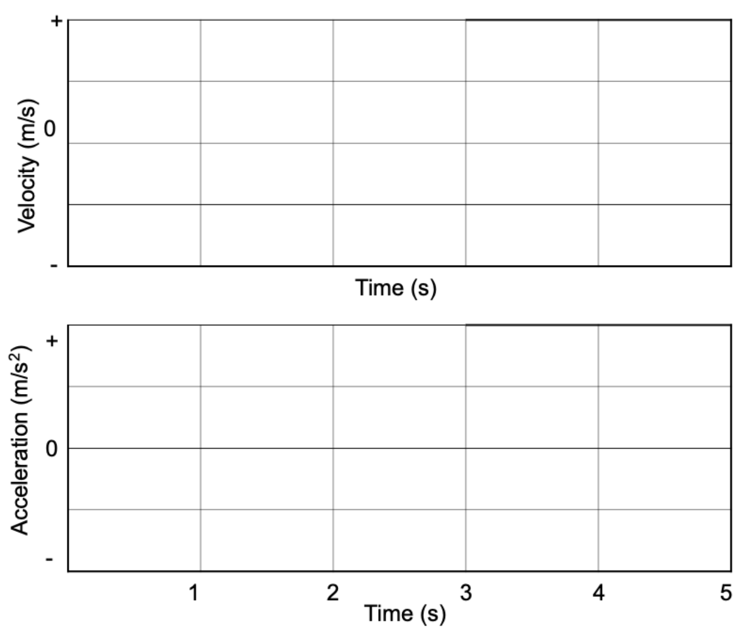
Question 1-8: How is the magnitude (value) of the acceleration represented on an acceleration vs. time graph?

Activity 1-3: Slowing Down

In the previous activity, when the cart began from rest and you turned on the fan, the cart began to speed up. Here, you will begin by turning on the fan, then giving the cart a push. You will examine the velocity and acceleration of this motion.

Prediction 1-2: If you give the cart with a fan a push in the positive direction while the fan tries to move it in the negative direction, will the acceleration from the fan be positive, negative, or zero (after it is released)?

Sketch your predictions for the velocity vs. time and acceleration vs. time graphs.

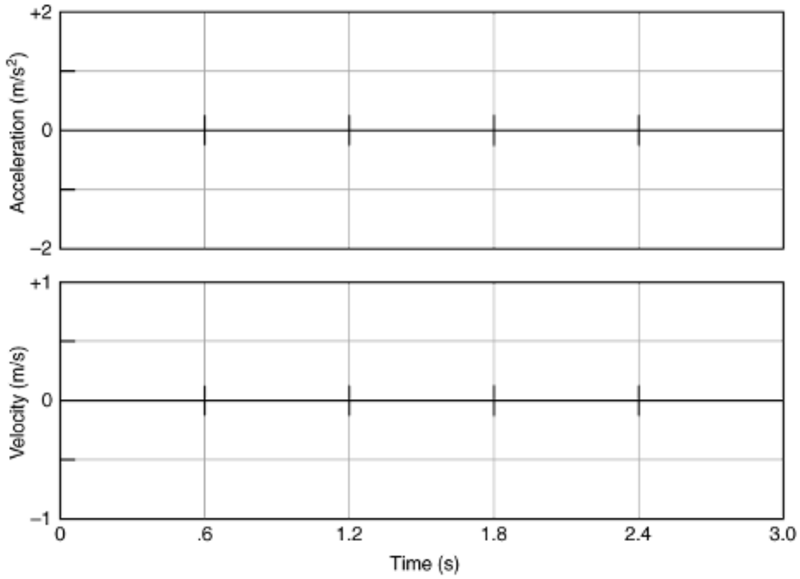


Test your predictions.

1. Turn the fan so that it is attached facing toward the **+x** arrow on the cart
2. Click to open Data Collection Settings. **Change End Collection to 5 s**, then click Done. Give the cart a quick push after you start collecting data. You may have to try a few times to get a good run.
3. Sketch your results neatly on the following graph. Label the graphs “Slowing Down.”

Circle AND LABEL the points or regions on your graphs with the following letters:

A. You are pushing the cart (region)
B. The fan is the only force on the cart (region)
C. The cart stopped moving (single point)



Question 1-9: Did the shapes of your velocity and acceleration graphs agree with your predictions? How is the sign of the acceleration represented on a velocity vs. time graph?

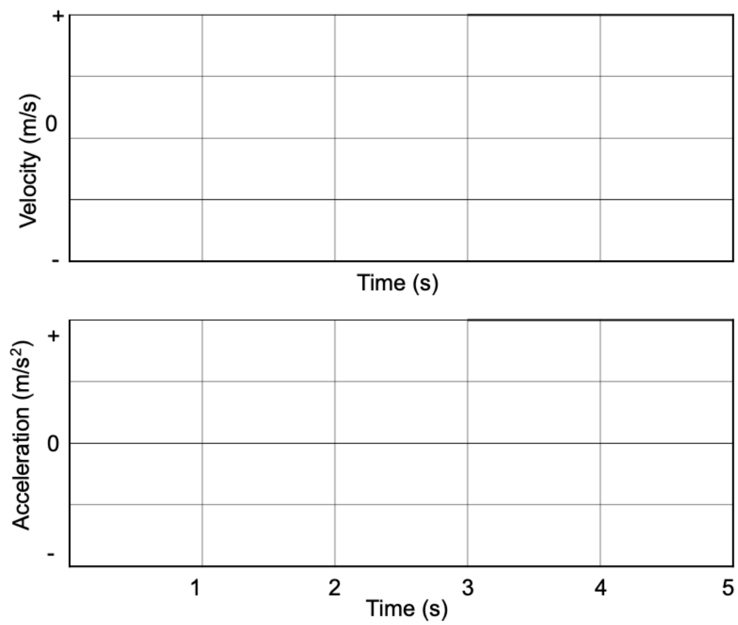
Question 1-10: How is the sign of the acceleration represented on an acceleration vs. time graph?

Question 1-11: Is the sign of the acceleration what you predicted? How does slowing down while moving in the positive direction result in this sign of acceleration? Hint: remember that acceleration is the rate of change of velocity. Look at how the velocity is changing.

Question 1-12: Based on your observations, if an object experiences a positive acceleration does that always mean it is speeding up?

Prediction 1-3: Suppose instead you start with the fan attached so it is facing **away from the +x** arrow on the cart, and you push the cart in the negative direction (opposite the **+x** arrow). If the cart moves in the negative direction and slows down, will the acceleration be positive or negative?

Sketch your predictions for the velocity vs. time and the acceleration vs. time graphs on the following graphs with a dotted line.



4. Test your predictions. Turn the fan so that it is attached facing away from the **+x** arrow on the cart.

5. Graph the cart moving in the negative direction and slowing down. Collect the data. Give the cart a gentle push in the negative direction (opposite the **+x** arrow) and release it.

Using a solid line, sketch the data on the same velocity and acceleration axes you used to draw your prediction. Label these new graphs as "Slowing Down with Negative Velocity."

Question 1-13: How does your velocity graph show that the cart was moving in the negative direction?

Question 1-14: During the time that the cart was slowing down, is the acceleration positive or negative? Does this agree with your prediction? Explain how slowing down while moving in the negative direction results in this sign of acceleration. Hint: look at how your graph is changing.

Question 1-15: Was your general rule in Question 1-10 correct? If not, modify it and restate it here.

Prediction 1-4: There is one more possible combination of velocity and acceleration for the cart: moving in the negative direction and speeding up. Use your general rule to predict the sign of the acceleration in this case. Explain why the acceleration should have this sign in terms of the sign of the velocity and how the velocity is changing.

Extension 1-4: Graphing Speeding Up with Negative Velocity

Adjust the fan attachment to test prediction 1-4. Graph the motion of the cart moving in the negative direction and speeding up.

Question E1-16: Compare the graphs to your answers to Prediction 1-4.

Question E1-17: Pick two points on your velocity graph and draw velocity vectors for them in the space below, labeling them $\mathbf{v_i}$ and $\mathbf{v_f}$. Then, show how the acceleration relates to the change in velocity between $\mathbf{v_i}$ and $\mathbf{v_f}$ using arrow subtraction.

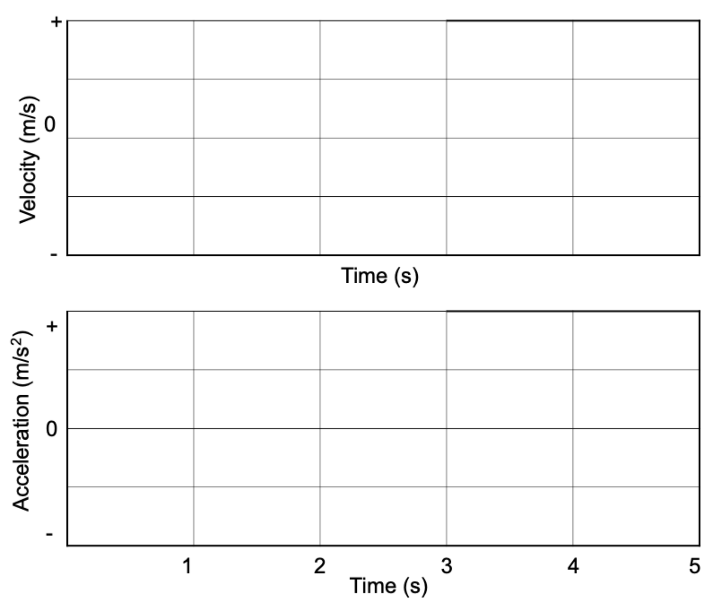
INVESTIGATION 2: MEASURING ACCELERATION

In this investigation you will analyze quantitatively (using numbers) the motion of a cart accelerated along a level surface by a battery driven fan. You will determine the cart's acceleration from your velocity vs. time graph and compare it to the acceleration read from the acceleration vs. time graph.

Activity 2-1: Velocity and Acceleration of a Cart That Is Speeding Up

1. Load the data for the cart accelerating along the ramp with half of the battery power (first half of Activity 1-1).

2. Sketch the velocity and acceleration graphs on the following axes or **print** and attach a copy of the graphs.



3. Calculate the average acceleration of the cart from your acceleration graph. **Click on the graph to read specific data points**. Read several values (say ten) of the acceleration that are equally spaced in time. (Only use values from the portion of the graph after the cart was released.)

Calculate the average value of the acceleration:

Acceleration Values (m/s^2)				
1.	3.	5.	7.	9.
2.	4.	6.	8.	10.
Average (mean) Acceleration:		m/s^2		

Comment: Average acceleration during a particular time period is the change in velocity divided by the change in time. This is the average rate of change of velocity. By definition, the rate of change of a quantity graphed with respect to time is also the slope of the curve. Thus the (average) slope of an object's velocity vs. time graph is the (average) acceleration of the object.

4. Calculate the average acceleration from your velocity graph. Calculate the slope of your velocity graph. Click on the acceleration graph and read the velocity and time coordinates for two typical points on the velocity graph. For a more accurate answer, use two points as far apart in time as possible but still during the time the cart was speeding up.

	Velocity (m/s)	Time (sec)
Point 1		
Point 2		

Calculate the change in velocity between points 1 and 2. Also calculate the corresponding change in time (time interval). Divide the change in velocity by the change in time. This is the average acceleration. Show your calculations below.

Speeding Up	
Change in velocity	m/s
Time interval	s
Average acceleration	m/s^2

Question 2-1: Is the acceleration positive or negative? Is that what you expected?

Question 2-2: Does the average acceleration you just calculated agree with the average acceleration you calculated from the acceleration graph? Do you expect them to agree? How would you account for any differences?

Activity 2-2: Speeding Up More

Note: You will need to save the data from this activity if you are doing Extension 2-3.

1. Load the data for the cart accelerating along the ramp with full battery power (second half of Activity 1-1).

2. Sketch the velocity and acceleration graphs or **print** and attach the graphs. Use dashed lines on the previous set of axes.

3. Calculate the average acceleration of the cart from your acceleration graph. Click on the graph to read acceleration values.

Acceleration Values (m/s^2)				
1.	3.	5.	7.	9.
2.	4.	6.	8.	10.
Average (mean) Acceleration:			m/s^2	

4. Calculate the average acceleration from your velocity graph. Calculate the slope of your velocity graph. Click on the velocity graph to read the velocity and time coordinates for two typical points. Remember to use two points as far apart in time as possible.

	Velocity (m/s)	Time (sec)
Point 1		
Point 2		

Calculate the average acceleration:

Speeding Up More	
Change in velocity	m/s
Time interval	s
Average acceleration	m/s^2

Question 2-3: Does the average acceleration calculated from velocities and times agree with the average acceleration you calculated from the acceleration graph? How would someone account for any differences?

Question 2-4: Compare this average acceleration to that with only three batteries and one dummy cell. Which is larger? Is this what you expected?

Extension 2-3: Using Statistics and Fit to Find the Average Acceleration

In Activities 2-1 and 2-2, you found the value of the average acceleration for a motion with steadily increasing velocity in two ways: from the average of a number of values on an acceleration vs. time graph, and from the slope of the velocity vs. time graph. The software allows you to find the average (mean) value directly from the acceleration vs. time graph and it allows you to find the line that best fits your velocity vs. time graph from Activities 2-1 and 2-2. The equation of this line includes a value for the slope.

1. Display the data from Activity 1-1 referred to as "Speeding Up." Select the portion of the acceleration vs. time graph for which you want to find the mean value.

Click on Graph Tools, , for the acceleration vs. time graph and choose View Statistics. Read the mean value of acceleration from the table: _______m/s^2

Question E2-5: How does this value compare to the one you found from the 10 measurements in Activity 2-1?

2. Select the portion of the velocity vs. time graph that you want to fit. Click on Graph Tools, , and choose Apply Curve Fit. Select Linear as the curve fit and click Apply.

The linear fit should correspond to the equation $v = b + ct$.

Record the equation of the fit line and compare the value of the slope (*c*) to the acceleration you found in Activity 2-1.

Question E2-6: What is the meaning of *b,* mathematically **and** in terms of the movement of the cart?

Question E2-7: How do the two values of acceleration that you found here compare to each other? Is this what you expected?

Question E2-8: Find the average acceleration for the motion in your "Speeding Up More" record from the acceleration vs. time and velocity vs. time graphs using the same methods. Compare the values to those found in Activity 2-2.

INVESTIGATION 3: SLOWING DOWN AND SPEEDING UP

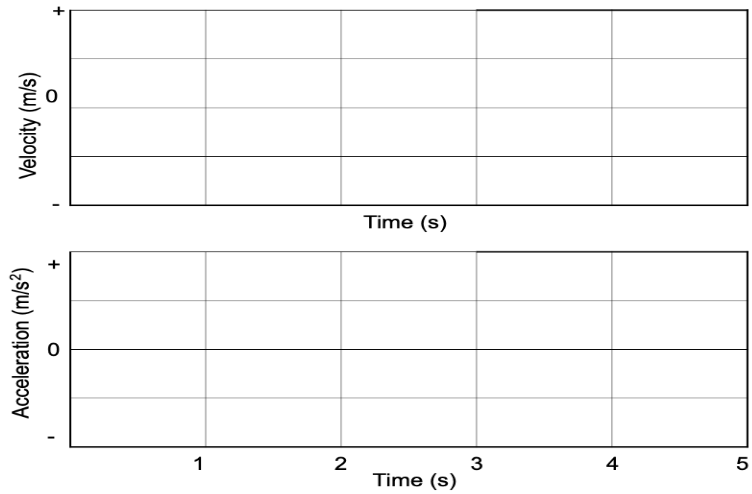
Activity 3-1: Reversing Direction

In this activity you will look at what happens when the cart slows down, reverses its direction, and then speeds up in the opposite direction. How does the velocity change with time for the cart? What is the cart's acceleration at each step?
The setup should be the same as before. The fan unit should have the maximum number of batteries and should be attached securely to the cart.

Prediction 3-1: You start the fan and give the cart a push in the positive direction. Once it leaves your hand moving away it slows down, reverses direction, and then moves back toward your hand. For each part of the motion, indicate in the table below whether the velocity is positive, zero, or negative. Also indicate whether the acceleration is positive, zero, or negative.

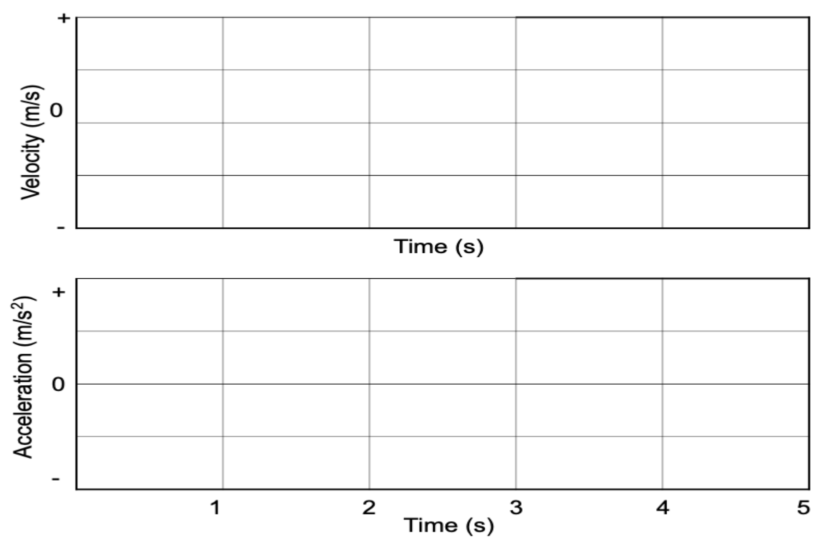
	Moving away	At the turning point	Moving toward
Velocity			
Acceleration			

Sketch your predictions for the cart's velocity vs. time and acceleration vs. time graphs.



1. Test your predictions. Graph the velocity and acceleration of the cart being pushed in the positive direction with the fan attached to push in the negative direction. Give the cart a quick push after you start collecting data.

2. When you get a good run, sketch both graphs on the axes below.



Circle the graph and label the following features with these letters:

A. where the cart was being pushed by your hand
B. where the cart is furthest from its original position (inflection point)
C. where the cart is moving fastest

Question 3-1: Explain how you know where each of these points is.

Question 3-2: Did the cart stop at its turning point? (Hint: look at the velocity graph. What was the velocity of the cart at its farthest point from the push?). Does this agree with your prediction?

Question 3-3: How much time did the cart spend at the turning point before it started moving back toward your hand? Explain.

Question 3-4: According to your acceleration graph, what is the acceleration at the instant the cart reaches the turning point? Is it positive, negative, or zero? Does this agree with your prediction?

Question 3-5: Explain the observed sign of the acceleration at the turning point (Hint: remember that acceleration is the rate of change of velocity. When the cart is at the top, what will its velocity be in the next instant? Will it be positive or negative?)

Question 3-6: On the way back toward your hand, is there any difference between these velocity and acceleration graphs and the ones in Activity 1-1 that were the result of the cart starting from rest? Explain.

Question 3-7: Compare the average acceleration of the cart while moving away from your hand and moving toward your hand. Are they the same? Base your answers on your velocity and acceleration graphs.

Activity 3-2: Sign of Acceleration

Question 3-8: Look at the acceleration graph you just produced in Activity 3-1 for the time periods when it was slowing down, at the turning point, and speeding up. What is the sign of the acceleration for each of these intervals? Explain why the acceleration has this sign in each case.

Question 3-9: You throw a ball straight up into the air. Assuming that upward is the positive direction, what is the sign of the velocity in the moments when the ball leaves your hand, reaches its highest point, and heads back down? Give your answers in the table below.

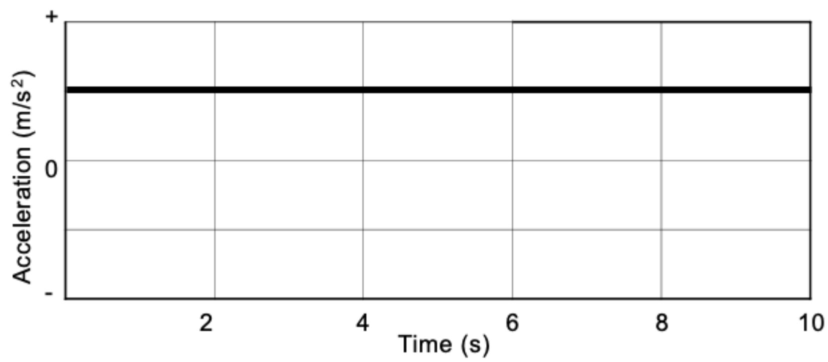
	Moving Up after Release	At highest point	Moving down
Velocity			
Acceleration			

Question 3-10: What forces acted on the cart in Activity 3-1 (after the push)? Does the force change direction when its moving away from your hand and toward it? What forces are acting on the ball (after the release)? Does that force have a different direction on the way up than on the way down?

Name: ______________________________ Date: _____________________

HOMEWORK FOR LAB 3:
CHANGING MOTION

After studying the acceleration and velocity graphs you made, answer the following questions.

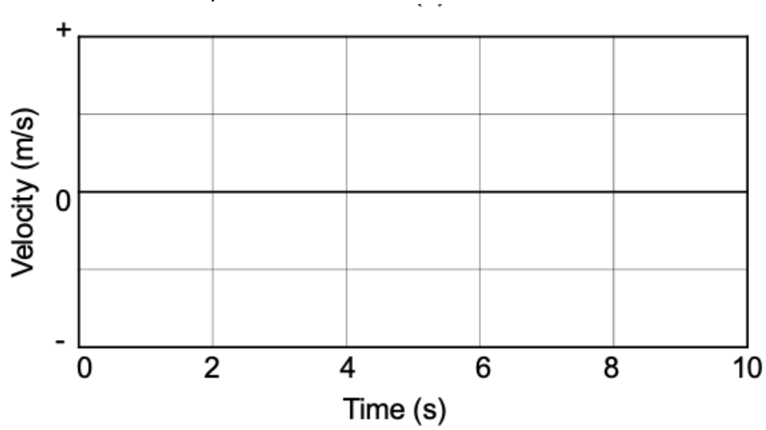


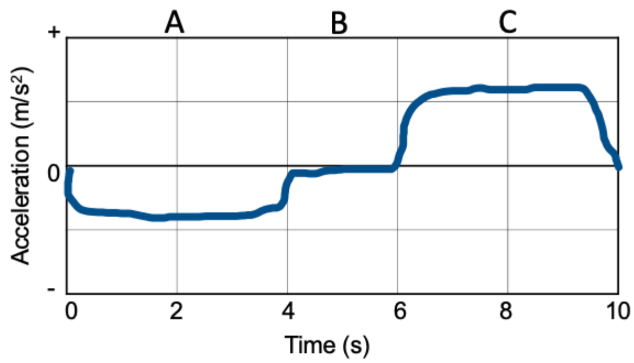
1. An object moving in a straight line experiences the acceleration shown in the graph above. How might the object move (speed up, slow down, constant velocity) to create this graph…

A. If it is moving away from the origin:

B. If it is moving toward the origin:

2. Sketch on the axes below the velocity-time graphs that go with the above acceleration vs. time. Sketch scenario A with a dotted line, and sketch scenario B with a solid line.





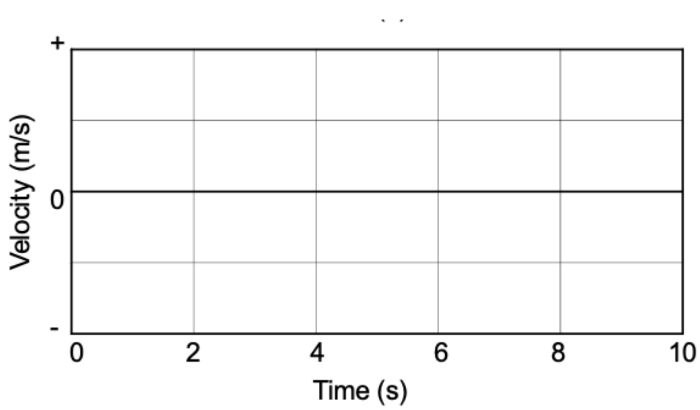
3. How would an object move to create each of the three labeled parts of the acceleration vs. time graph above?

A: ____

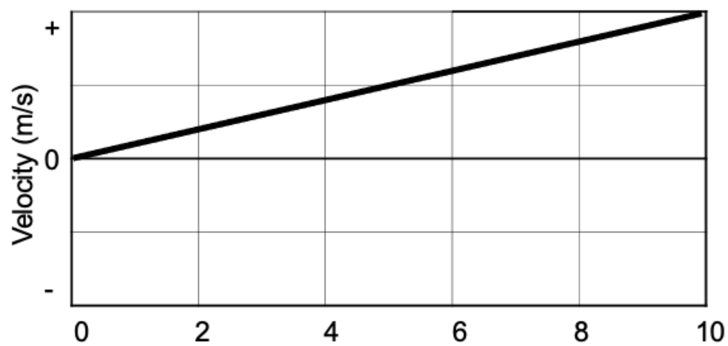
B: ____

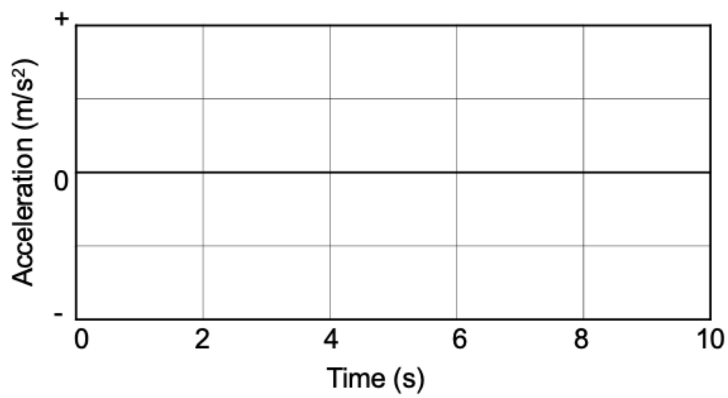
C: ____

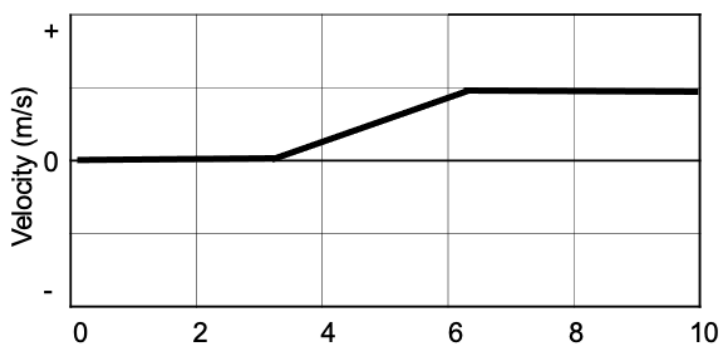
4. Sketch a velocity vs. time graph which might go with the above acceleration vs. time graph.

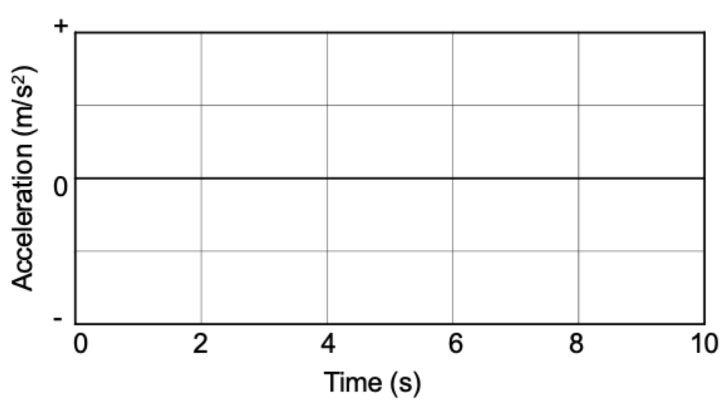


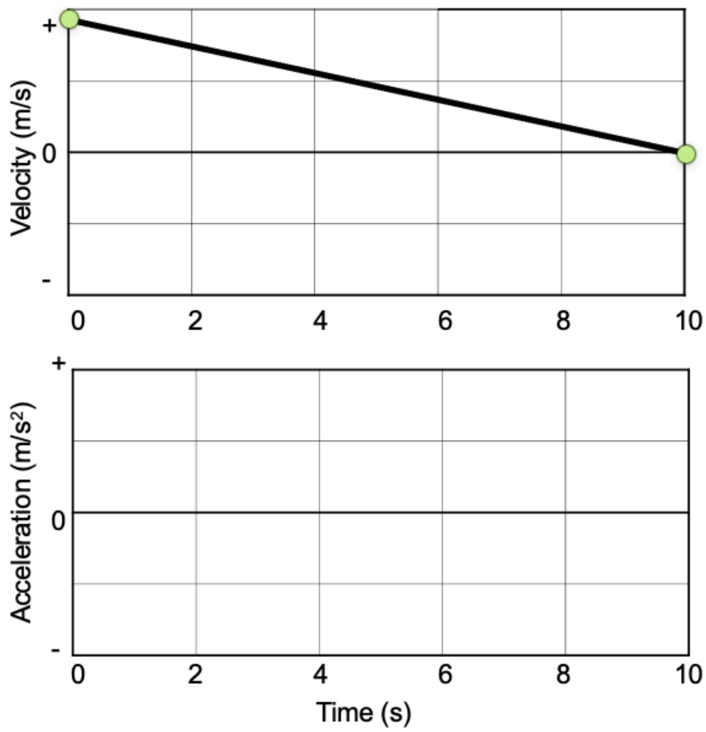
5. Sketch the acceleration vs. time graph that goes with each velocity vs. time graph above it.







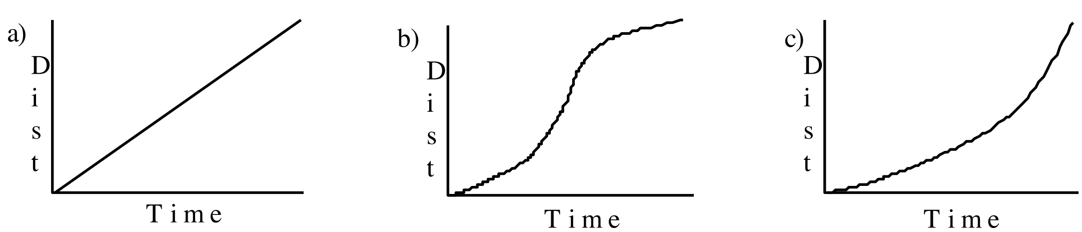




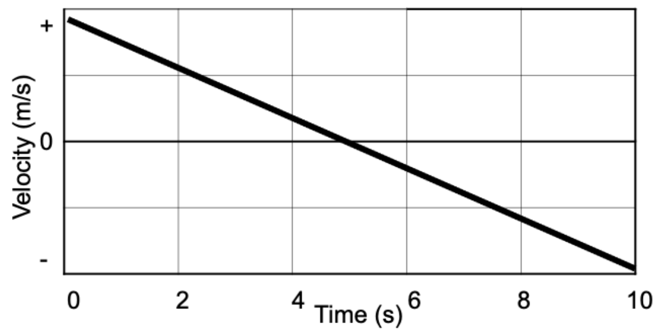
6. A car moves along a line [the + distance (position) axis]. Fill in the table below with the sign (+ or -) of the velocity and acceleration of the car for each of the motions described.

	Distance (Position)	Velocity	Acceleration Speeding Up	Acceleration Slowing Down
Car moves away from the origin	+			
Car moves toward the origin	+			

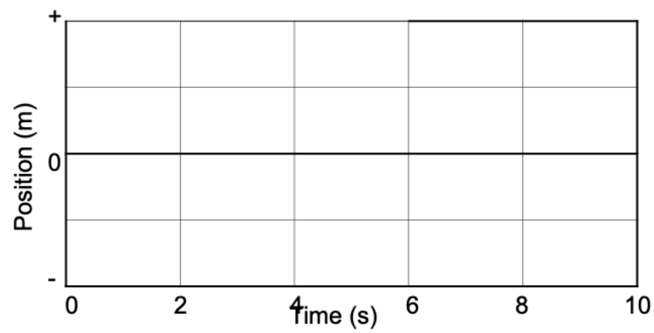
7. Which position vs. time graph below could be that for a cart that is steadily accelerating away from the origin?



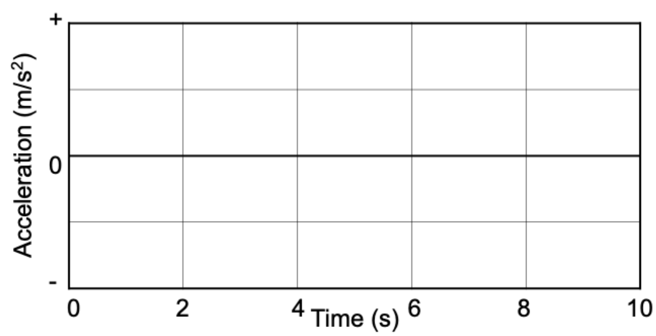
8. Describe how you would move to produce the velocity vs. time graph on the right.



9. Sketch a position vs. time graph for this motion on the axes to the right.

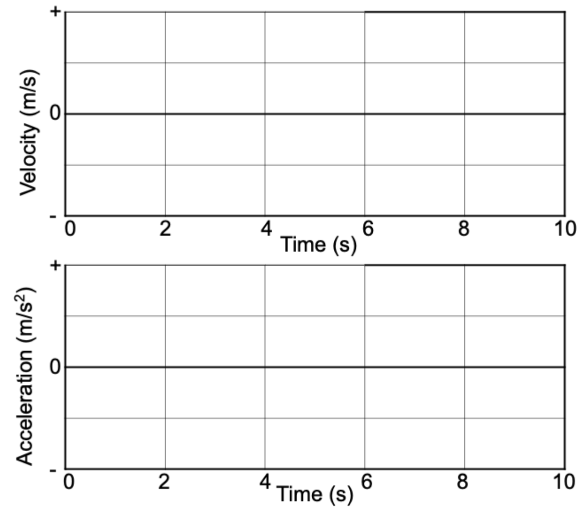


10. Sketch an acceleration vs. time graph for this motion on the axes to the right.

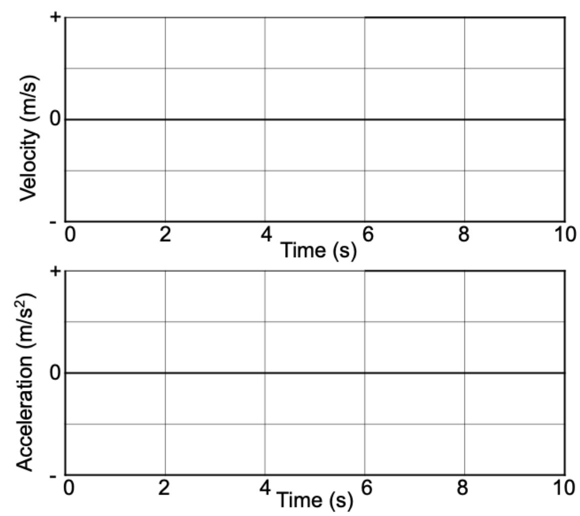


A car can move in either direction along a line (the + distance axis). Sketch velocity vs. time and acceleration vs. time graphs which correspond to each of the following descriptions of the car's motion.

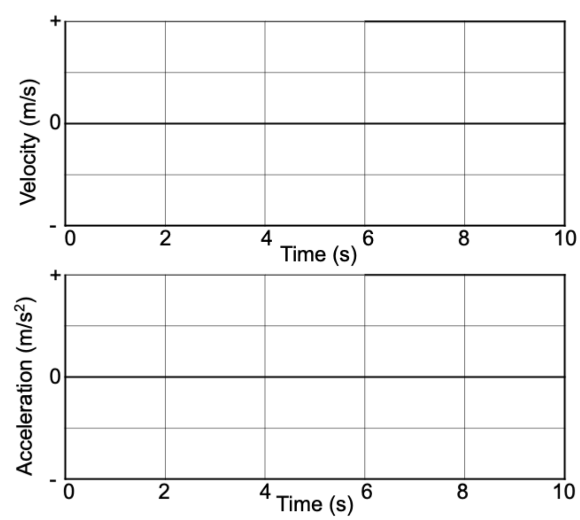
11. The cart starts from rest and moves away from the origin increasing its speed at a steady rate.



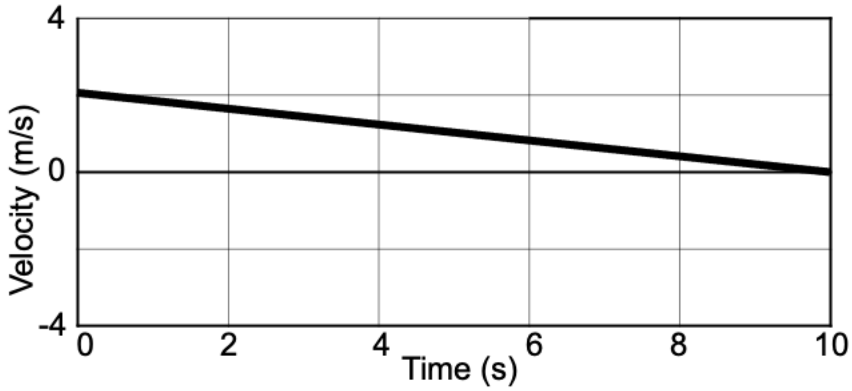
12. The car is moving toward the origin at a constant velocity.



13. The car starts from rest and moves toward the origin speeding up at a steady rate.

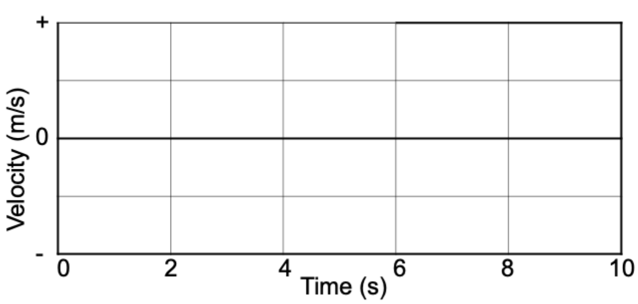


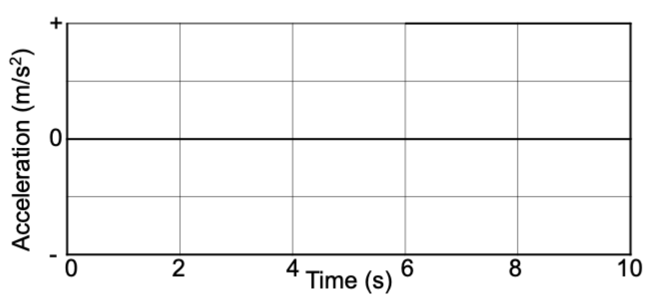
14. The following is a velocity vs. time graph for a car.



What is the average acceleration of the car? Show your work below.

15. A ball is tossed in the air. It moves upward, reaches its highest point and falls back downward. Sketch a velocity-time and an acceleration-time graph for the ball from the moment it leaves the thrower's hand until the moment just before it reaches her hand again. Consider the positive direction to be <u>upward.</u>





The graphs on this page represent the motion of objects along a line which is the positive distance (position) axis. Notice that the motion of objects is represented by distance, velocity, or acceleration graphs.

Answer the following questions. You may use a graph more than once or not at all and there may be more correct choices than blanks. If none of the graphs is correct, answer J.

____16. Pick one graph that gives enough information to indicate that the velocity is always negative.

Pick three graphs that represent the motion of an object whose velocity is constant (not changing)

____17. ____18. ____19.

____20. Pick one graph that <u>definitely indicates an object has reversed direction.</u>

____21. Pick one graph that might possibly be that of an object standing still.

Pick 3 graphs that represent the motion of objects whose acceleration is changing.

____22. ____23. ____24.

Pick a velocity graph and an acceleration graph that could describe the motion of the same object during the time shown.

____25. Velocity graph.

____26. Acceleration graph