NATIONAL MATH + SCIENCE INITIATIVE

Constantly Changing Velocity

Walking Acceleration Lab

MATERIALS

book

cart and track

computer

LabQuest®

sensor, motion detector

ruler, clear metric

stopwatch

One of the most effective methods of describing motion is to plot graphs of position, which is velocity vs. time. From such a graphical representation, it is possible to determine in what direction an object is moving, how fast it is moving, how far it has traveled, and whether it is speeding up or slowing down. A qualitative analysis of the graphs of your classmates' motion will help you understand the concepts of kinematics.

PURPOSE

In Part I, you will find the speed at particular times of a walker traveling at a constantly increasing speed by finding the slope at intervals along a distance vs. time graph.

In Part II, you will be asked to predict the shape of the curve when a cart is rolled away from a motion detector located at the top of a slope, and toward a motion detector located at the bottom of a slope.

PROCEDURE

PART I: DISTANCE VS. TIME FOR AN INCREASING SPEED

1. Mark a hallway or sidewalk with tape at 5-m intervals.
2. Choose one person to be the designated walker/jogger/runner for the course. The person doing the walking/jogging/running must try to increase each segment slowly so that they still have some ability to speed up as they reach the end of the course.
3. Position one or more participants with stopwatches at each of the 5-m marks, and assign another class member to be the record keeper.
4. When the walker is ready, they should say "Go!" and all timers should start their stopwatches. As the walker passes the timing station, the timers should stop their stopwatches.
5. At the end of the run, the record keeper should record the time values from each timing station.
6. Continue running trials until you get a trial with fairly consistently decreasing times between successive timing stations.
7. When the data gathering is finished, all students should copy the class data into their data table and complete the graphing and data analysis individually.

PROCEDURE (CONTINUED)

PART II: PREDICTING GRAPHS

Four scenarios are described in this section. Each scenario involves placing a motion detector along a track and using a cart to generate a distance vs. time graph.

Before beginning data collection, be sure to:

- Sketch your apparatus.
- Predict the result of your distance vs. time graph.
- Predict the result of your velocity vs. time graph.

SCENARIO ONE

Place the motion detector and the top of the track on a book. Place the cart on the track about 15 cm in front of the motion detector. Using Logger *Pro*, collect data as the cart is released and rolls away from the detector. After completing the run, sketch your actual graph in a different color than your prediction. Label both lines.

SCENARIO TWO

Place the end of the track on a book and the motion detector at the bottom of the track at the opposite end. Place the cart on the track at the top and allow it to roll toward the motion detector. Be sure to catch the cart before it hits the motion detector. Using Logger *Pro*, collect data as the cart is released and rolls toward the detector. After completing the run, sketch your actual graph in a different color than your prediction. Label both lines.

SCENARIO THREE

A student sets up the equipment, rolls the cart and obtains the graph as shown in Figure 3. Make a sketch showing the position of the motion detector, the orientation of the ramp, and the direction of motion of the cart on the ramp. Draw a prediction of the corresponding velocity vs. time graph. Also, describe the motion of the cart necessary to produce this graph.

SCENARIO FOUR

A student sets up the equipment and gives the cart a push up the ramp, and then the cart rolls back down on its own. Draw your prediction for the shape of the position vs. time graph and for the velocity vs. time graph. Set up the trial and then draw your graphs of actual data collected in a different color. Label both sets of lines.

DATA AND OBSERVATIONS

Table 1. Constantly Changing Velocity

Timer	Position (m)	Time (s)	Midpoint (s)	Slope (m/s)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

ANALYSIS

PART I: DISTANCE VS. TIME FOR AN INCREASING SPEED

1. Plot a graph of distance on the vertical axis versus time on the horizontal axis for your group's walker.

2. Calculate the slope for each interval on your graph. Draw a straight line connecting each two points, and then find the slope of these straight lines. Record these values in the data table.

3. On a second graph, plot the slope vs. the midpoint time, given as

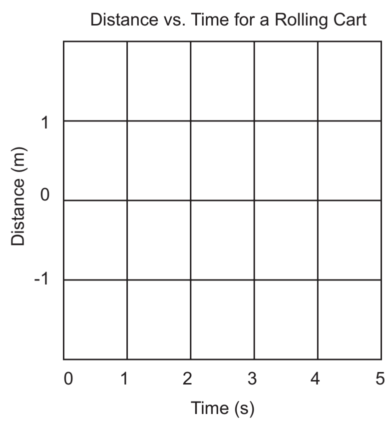
$$\frac{t_f + t_i}{2}$$

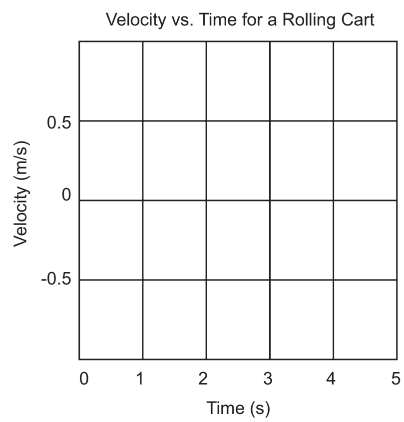
   Draw the best fit straight line through this data, and then find the slope of this line. Be sure to include the units.

4. Derive an equation for the best fit straight line drawn though your data for the velocity vs. time graph. Express this equation in terms of the slope. What is the significance of the slope, and what are the units of this value?

ANALYSIS (CONTINUED)

PART II: PREDICTING GRAPHS

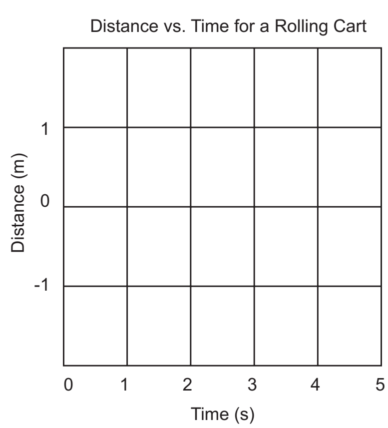


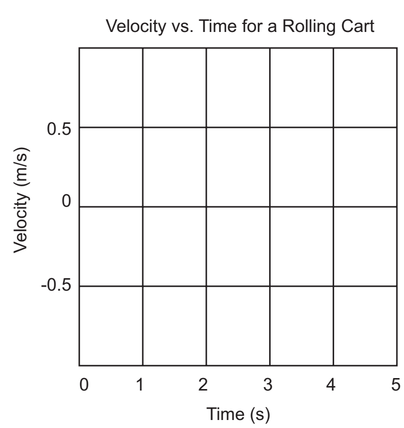


SCENARIO ONE

Equipment Sketch:

SCENARIO TWO

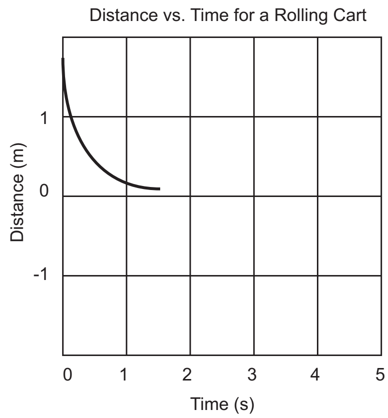


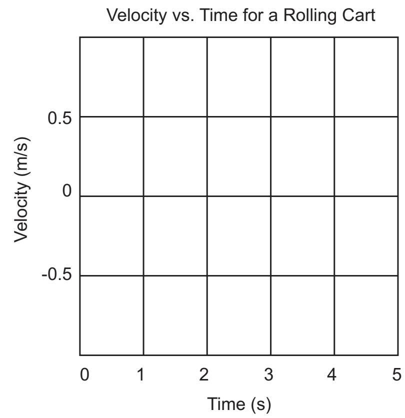


Equipment Sketch:

ANALYSIS (CONTINUED)

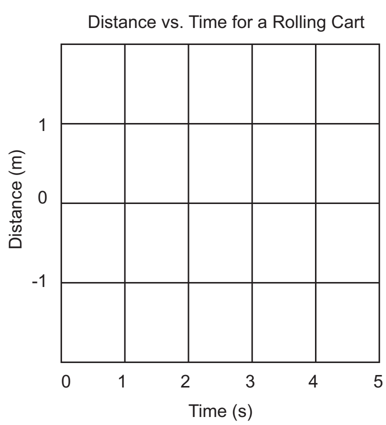
SCENARIO THREE

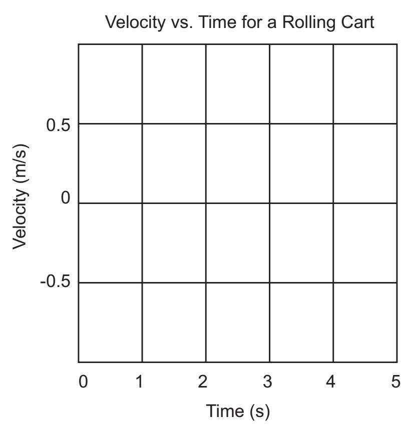




Equipment Sketch:

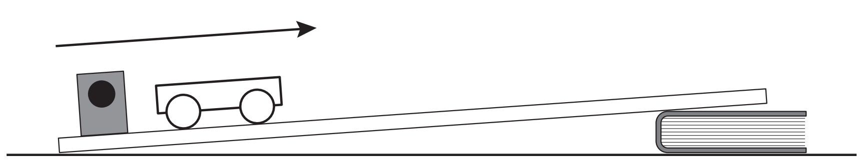
Describe the motion of the cart necessary to produce this distance vs. time graph.





SCENARIO FOUR

Equipment Sketch:



CONCLUSION QUESTIONS

1. What is the significance of the change in slope of the intervals as the walker continued increasing in speed as they went down the course?

2. Write a general statement summarizing the concepts and results of this lab.

3. List two reasonable sources of error in this lab, and describe how each may have affected your results.

4. What type of motion is occurring when the slope of a position vs. time graph is changing?

5. When you plotted your data and drew the best fit line, why were some of the data points not located directly on your best fit line?

CONCLUSION QUESTIONS (CONTINUED)

6. When you drew your best fit line, did the line go through the origin at (0,0)? If not, what would the significance of a y-intercept have on your data? If the walker had started at some point other than the zero line, would this have affected the y-intercept of your graph?

7. In Part II of this lab, what is the relationship between the shape of the position vs. time graph and the velocity vs. time graph?

GOING FURTHER

Have one student re-walk the course at a constantly increasing speed, but have the student start 5 m behind the original starting line. This method will also require timers at the zero line as well as timers at the other locations. Graph the data, and explain the significance of any x- or y-intercepts.

Have one student re-walk the course at a constantly increasing speed, but have the student start 5 m in front of the original starting line. This method will not require timers at the zero line. Graph the data, and explain the significance of any x- or y- intercepts.

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