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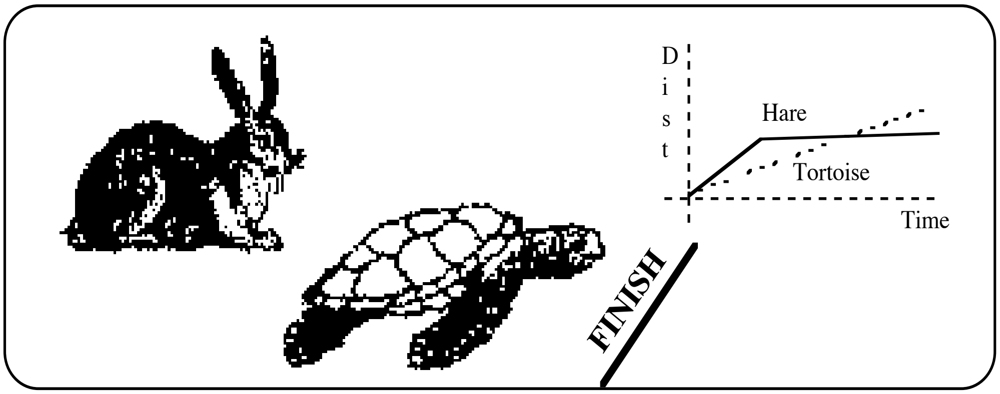
Partners:__________________________________Date:____________________

Physics 100 LAB 1: INTRODUCTION TO MOTION



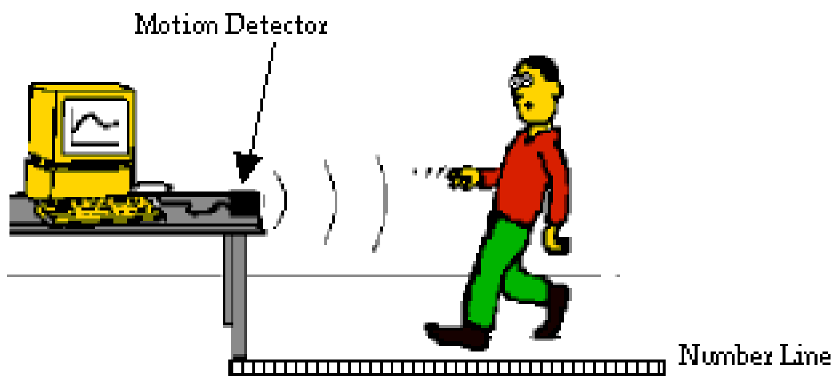
The purpose of these exercises is to let you get a feeling for position, velocity and acceleration, not to make extremely accurate measurements.

OBJECTIVES

- To discover how to measure motion with a motion detector
- To see how motion looks as a distance (position)-time graph
- To see how motion looks as a velocity-time graph
- To discover the relationship between position-time and velocity-time graphs.

OVERVIEW

In this unit you will examine two different ways that the motion of an object can be represented graphically. You will use a motion detector to plot distance (position) and velocity-time graphs of the motion of your body. The study of motion and its mathematical and graphical representation is known as *kinematics.*



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Note: These materials have been edited at Simon Fraser University by N. Alberding

INVESTIGATION 1: DISTANCE (POSITION)-TIME GRAPHS OF YOUR MOTION

The purpose of this investigation is to learn how to relate graphs of distance as a function of time to the motions they represent.

You will use the following materials:

- *Logger Pro®* software
- *Physics 100* Experiments folder
- *Go!Motion®* motion detector
- Number line on floor in meters (optional)

How does the distance-time graph look when you move slowly? Quickly? What happens when you move toward the motion detector? Away? After completing this investigation, you should be able to look at a distance-time graph and describe the motion of an object. You should also be able to look at the motion of an object and sketch a graph representing that motion.

Comment: "Distance" is short for "distance from the motion detector." The motion detector is the origin from which distances are measured.

- It detects the closest object directly in front of it (including your arms if you swing them as you walk).
- It will not correctly measure anything closer than 0.15 meter. (*When making your graphs don't go closer than 0.15 meter from the motion detector.*)
- As you walk (or jump, or run), the graph on the computer screen displays how far away from the detector you are.

Activity 1-1: Making Distance-Time Graphs (should take about 5 minutes)

1. Make sure the computer is turned on and the Physics 100 folder is visible. (Ask a TA to help if it isn't) Use the mouse to click on the file **L1 #1.cmbl**. The graph axes should appear on the screen. (Be sure the motion detector is plugged into a USB port at the back of the computer.)
2. When you are ready to start graphing distance, click once on the green "**Collect**" button in the top middle of the screen.
3. If you have a number line on the floor or on the edge of your bench, and you want the detector to produce readings that agree, stand at the 2-meter mark on the number line and have someone move the detector until the reading is 2 m.
4. Make distance-time graphs for different walking speeds and directions, and sketch your graphs on the axes.

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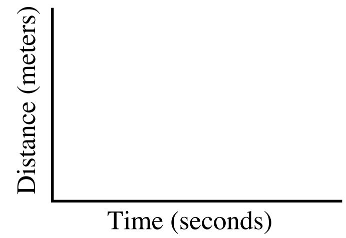
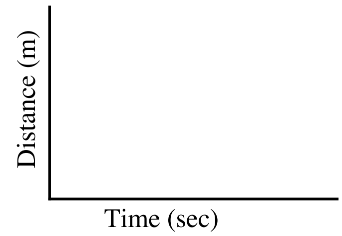
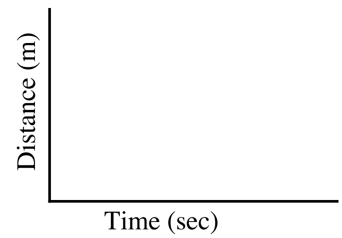
a. Start at the 1/2-meter mark and make a distance-time graph, walking away from the detector (origin) *slowly and steadily*.



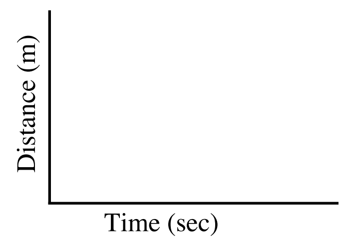
b. Make a distance-time graph, walking away from the detector (origin) *medium fast and steadily*.



c. Make a distance-time graph, walking toward the detector (origin) *slowly and steadily*.



d. Make a distance-time graph, walking toward the detector (origin) *medium fast and steadily*.



Comment: It is common to refer to the distance of an object from some origin as the *position* of the object. Since the motion detector is at the origin of the coordinate system, it is better to refer to the graphs you have made as *position-time* graphs. From now on you will plot *position-time* graphs.

Activity 1-2: Matching a Position Graph (approx. 10 min)

By now you should be pretty good at predicting the shape of a graph of your movements. Can you do things the other way around by reading a position-time graph and figuring out how to move to reproduce it? In this activity you will match a position graph shown on the computer screen.

1. Open the experiment file called **L1 #2 (Position Match).cmbl** from the Physics 100 folder. A position graph like that shown below will appear on the screen.

Comment: This graph is stored in the computer as Match Data. New data from the motion detector are always stored as Latest Run, and can therefore be collected without erasing the **Position Match** graph.

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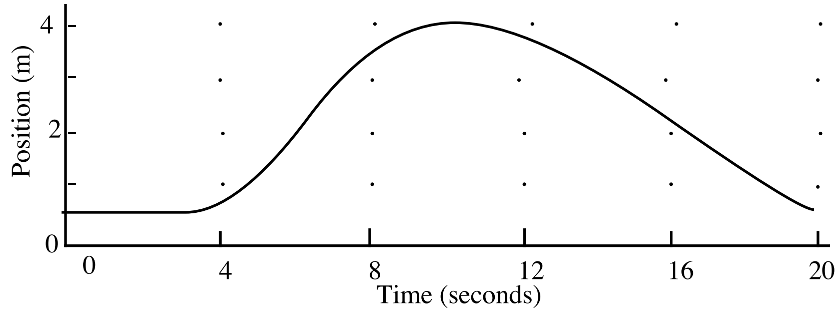

Clear any data remaining from previous experiments in Latest Run by selecting **Clear Latest Run** from the Experiment Menu.

2. Move to match the **Position Match** graph on the computer screen. You may try a number of times. It helps to work in a team. Get the times right. Get the positions right. Each person should take a turn. Sketch the best attempt on the graph.

INVESTIGATION 2: VELOCITY-TIME GRAPHS OF MOTION

You have already plotted your position as a function of time. Another way to represent your motion during an interval of time is with a graph, which describes how fast and in what direction you are moving. This is a *velocity-time* graph. *Velocity* is the rate of change of position with respect to time. It is a quantity, which takes into account your speed (how fast you are moving) and also the direction you are moving. Thus, when you examine the motion of an object moving along a line, its velocity can be positive or negative meaning the velocity is in the positive or negative direction.

Graphs of velocity vs. time are more challenging to create and interpret than those for position. A good way to learn to interpret them is to create and examine velocity-time graphs of your own body motions, as you will do in this investigation.

Activity 2-1: Making Velocity Graphs (approx. 5 min)

1. Set up to graph velocity. Open the experiment **L1 #3 (Velocity Graphs)**. Make sure that the **Velocity** axis is set to read from **-1** to **1** m/sec and the **Time** axis from **0** to **5** sec, as shown on the next page.

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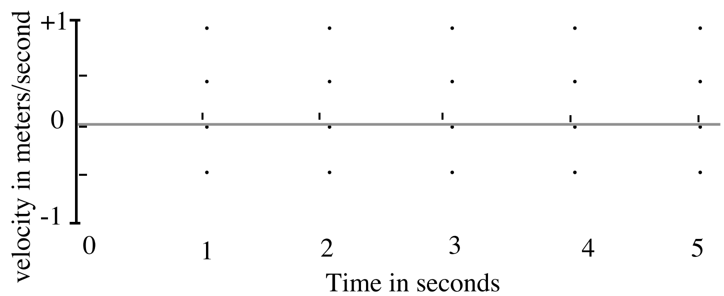
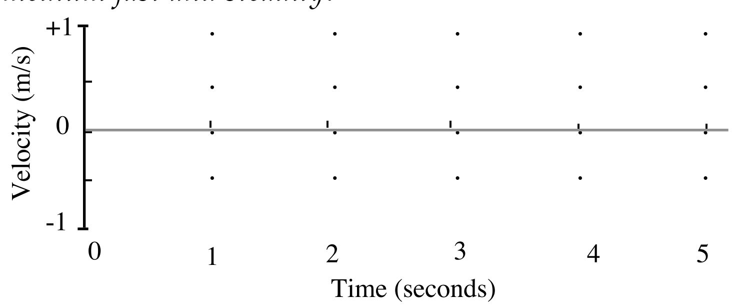
2. Graph your velocity for different walking speeds and directions, and sketch your graphs on the axes. (**Just draw *smooth* patterns; leave out smaller bumps that are mostly due to your steps.**)

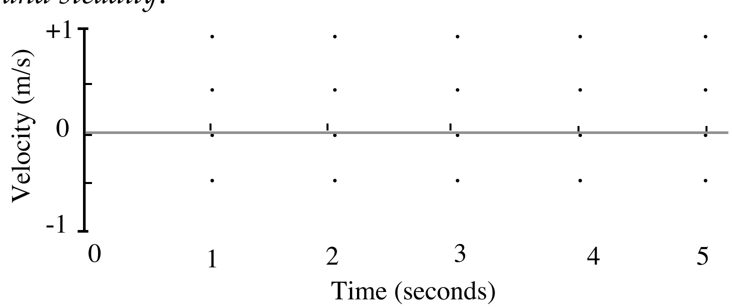
a. Make a velocity graph by walking *away* from the detector *slowly and steadily*. Try again until you get a graph you're satisfied with. Then sketch your graph on the axes below.



b. Make a velocity graph, walking *away* from the detector *medium fast and steadily*.



c. Make a velocity graph, walking *toward* the detector *slowly and steadily*.



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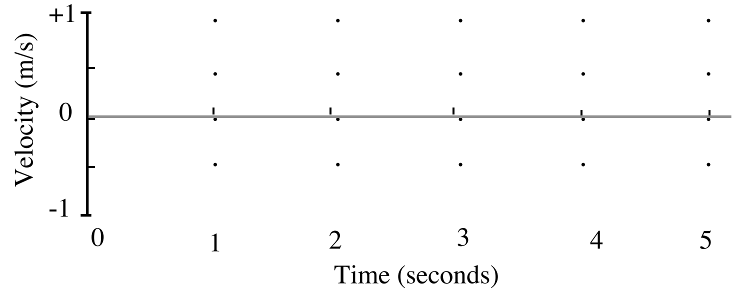
d. Make a velocity graph, walking *toward* the detector *medium fast and steadily*.



*** **IMPORTANT Comment:** You may want to change the velocity scale so that a graph fills more of the screen and is clearer. To do this, use the mouse to double click anywhere on the graph and change the velocity range in the dialog box. Another way to do this is to click the mouse once with the cursor pointing to the maximum axis reading. Type in the new value and hit **return.**

Activity 2-2 Predicting a Velocity Graph (approx. 5 min)

Prediction 2-1: Predict a velocity graph for a more complicated motion and check your prediction.

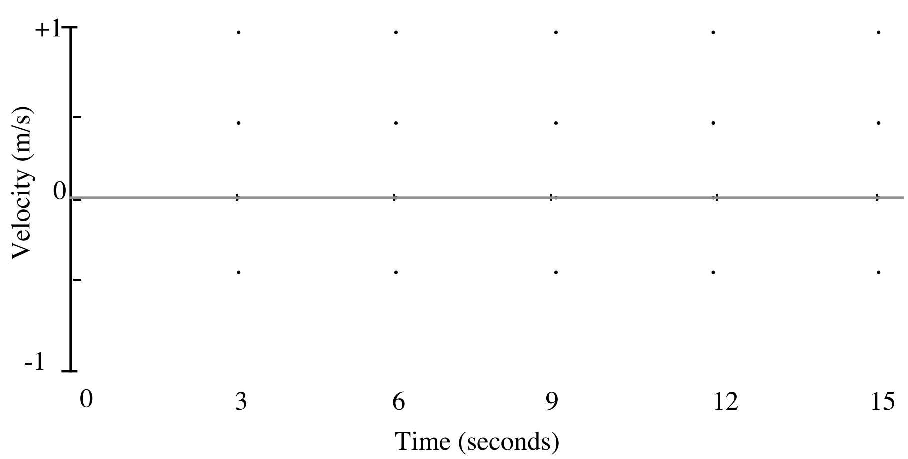
Each person draw below, using a *dashed line* your *prediction* of the velocity graph produced if you:

- Walk away from the detector slowly and steadily for about 5 seconds, then stand still for about 5 seconds, then walk toward the detector steadily about twice as fast as before

Compare your predictions and see if you can all agree. Use a solid line to draw in your group prediction.

(To get desired scaling on the axis, read **Comment** above)

PREDICTION



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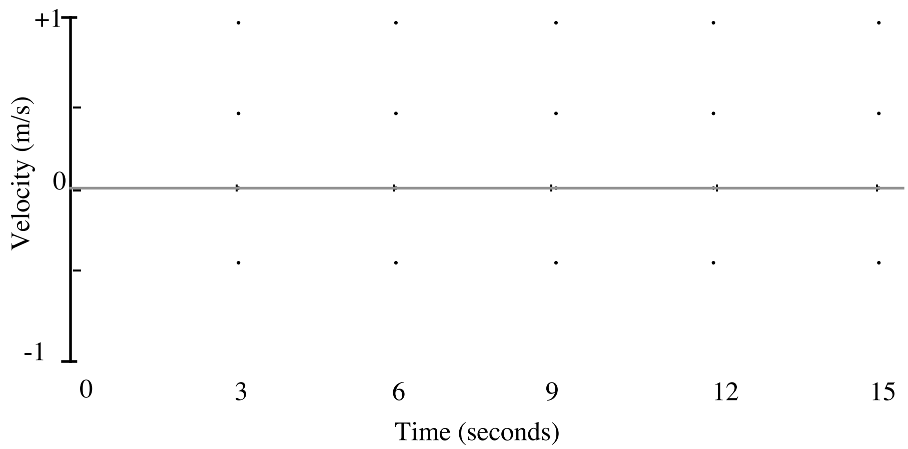
3. Test your prediction. (Be sure to adjust the time scale to 15 seconds. As before, this can be done by clicking the mouse once on the 5 to highlight it, typing in a 15 and then hitting the **return** key.) Repeat your motion until you think it matches the description.

   Draw the best graph on the axes below. **Be sure the 5-second stop shows clearly.**

FINAL RESULT



INVESTIGATION 3: RELATING POSITION AND VELOCITY GRAPHS

Since position-time and velocity-time graphs are different ways to represent the same motion, it ought to be possible to figure out the velocity at which someone is moving by examining her/his position-time graph. Conversely, you ought to be able to figure out how far someone has traveled (change in position) from a velocity-time graph.

Activity 3-1: Predicting Velocity Graphs from Position Graphs(approx 10 min)

1. Set up to graph Position and Velocity. Open the experiment **L1 #5 (Velocity from Position)** to set up the top graph to display **Position** from **0** to **4** m for a time of **5** sec, and the bottom graph to display **Velocity** from **-2** to **2** m/sec for **5** sec. Clear any previous graphs.

Prediction 3-1: Predict a velocity graph from a position graph. Carefully study the position-time graph shown below and predict the velocity-time graph that would result from the motion. Using a *dashed line*, sketch your *prediction* of the corresponding velocity-time graph on the velocity axes.

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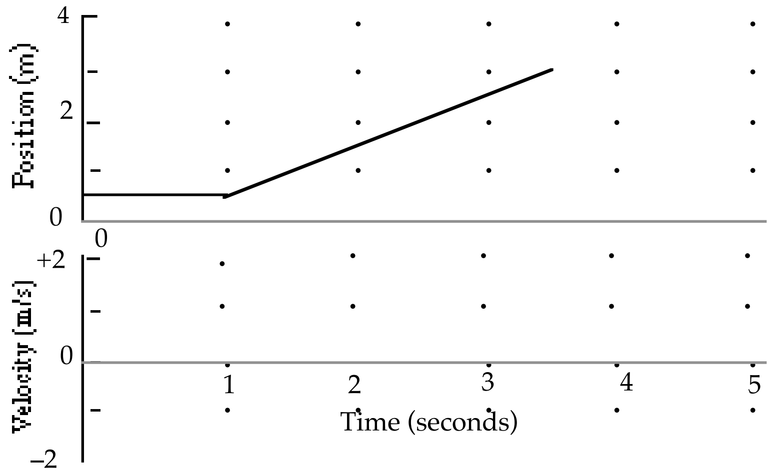

2. Test your prediction. After each person has sketched a prediction, **Collect,** and do your group's best to make a position graph like the one shown. Walk as smoothly as possible.

   When you have made a good duplicate of the position graph, sketch your actual graph over the existing position-time graph.

   Use a *solid line* to draw the actual velocity graph on the same graph with your prediction. (Do not erase your prediction).

Activity 3-2: Calculating Average Velocity (approx 10 min)

In this activity, you will find an average velocity from your velocity graph in Activity 3-1 and then from your position graph.

1. Find your average velocity from your velocity graph in Activity 3-1. Select **Examine** in the Analyze menu, read a number of values (say five) *from the portion of your velocity graph where your velocity is relatively constant*, and use them to calculate the average (mean) velocity. Write the five values in the table below.

	Velocity Values (m/s)
1	
2	
3	
4	
5	

   Average value of the velocity: _________m/s

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Comment: Average velocity during a particular time interval can also be calculated as the change in position divided by the change in time. (The change in position is often called the *displacement.*) By definition, this is also the *slope* of the position-time graph for that time period.

As you have observed, the faster you move, the more inclined is your position-time graph. The *slope* of a position-time graph is a quantitative measure of this incline, and therefore it tells you the velocity of the object.

2. Calculate your average velocity from the slope of your position graph in Activity 3-1. Use **Examine** to read the position and time coordinates for two typical points *while you were moving*. (For a more accurate answer, use two points as far apart as possible but still typical of the motion, and within the time interval over which you took velocity readings in (1).)

	Position (m)	Time (sec)
Point 1		
Point 2		

Calculate the change in position (displacement) between points 1 and 2. Also calculate the corresponding change in time (time interval). Divide the change in position by the change in time to calculate the *average* velocity. Show your calculations below.

Change in position (m)	
Time interval (sec)	
Average velocity (m/s)	

Activity 3-3: Predicting Position Graphs from Velocity Graphs (approx 10 min)

Prediction 3-2: Carefully study the **velocity** graph shown below. Using a *dashed line*, **sketch** your *prediction* of the corresponding **position** graph on the bottom set of axes. (Assume that you started at the 1-meter mark.)

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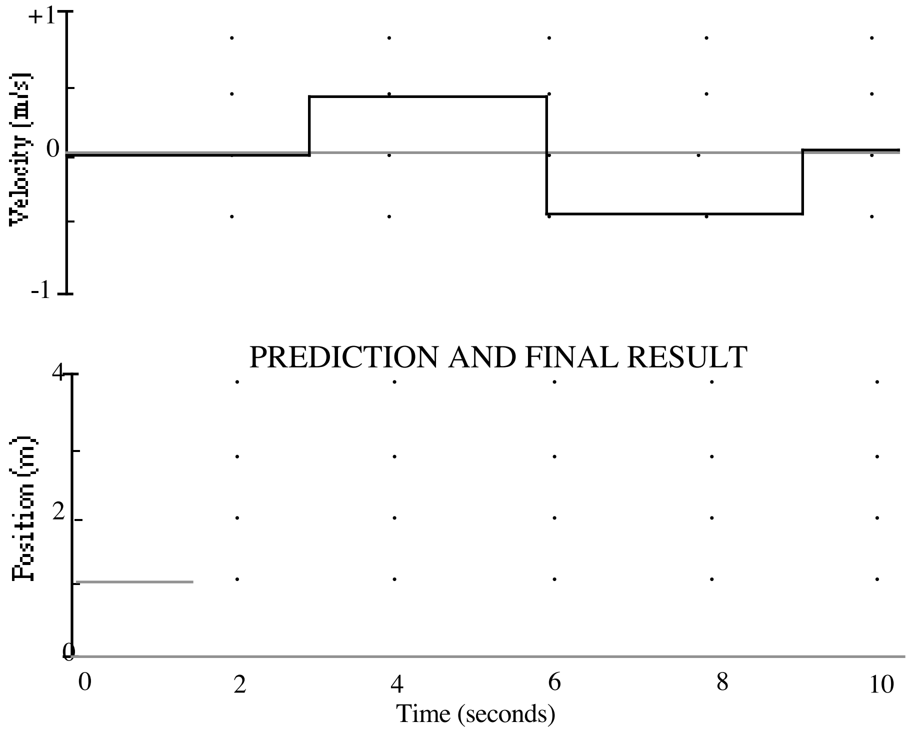

Test your prediction.

1. Open the experiment **L1 #6 (Position from Velocity).**
2. After each person has sketched a prediction, do your group's best to duplicate the top (velocity-time) graph by walking. Be sure to graph velocity first.

   When you have made a good duplicate of the velocity-time graph, draw your actual result over the existing velocity-time graph.
3. Use a *solid line* to draw the actual position-time graph on the same axes with your prediction. (Do not erase your prediction.)

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Study questions may be answered after the lab

Investigation 1

1-1: Describe the difference between the graph you made by walking away *slowly* and the one made by walking away *more quickly*.

1-2: Describe the difference between the graph made by walking *toward* and the one made walking *away from* the motion detector.

1-3: Describe the motions that you did to match the graph in Activity 1-2.

Investigation 2

2-1: What is the most important difference between the graph made by *slowly* walking away from the detector and the one made by walking away *more quickly*?

2-2: How are the velocity-time graphs different for motion *away from* the detector compared to those for motion *towards* the detector?

2-3: Describe how you moved
1) when the velocity line was above horizontal zero line.

2) when the velocity line was crossing the horizontal zero line

3) when the velocity line was below zero.

2-4: Is it possible for an object to move so that it produces an absolutely vertical line on a velocity time graph? Explain.

2-5: Did you run into the motion detector on your return trip? If so, why did this happen? How did you solve the problem? Does a velocity graph tell you where to start? Explain.

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Investigation 3

3-1: How would the position graph be different if you moved faster? Slower?

3-2: How would the velocity graph be different if you moved faster? slower?

3-3: Is the average velocity positive or negative? Is this what you expected?

3-4: Does the average velocity you calculated from the position graph agree with the average velocity you found from the velocity graph? Do you expect them to agree? How would you account for any differences?

3-5: How can you tell from a **velocity**-time graph that the moving object has changed direction?

3-6: What is the velocity at the moment the direction changes (i.e, the sign of v changes from positive to negative)?

3-7: Is it possible to actually move your body (or an object) to make **vertical** lines on a position-time graph? Why or why not? What would the velocity be for a vertical section of a position-time graph?

3-8: How can you tell from a position-time graph that your motion is steady (motion at a constant velocity)?

3-9: How can you tell from a velocity-time graph that your motion is steady (constant velocity)?

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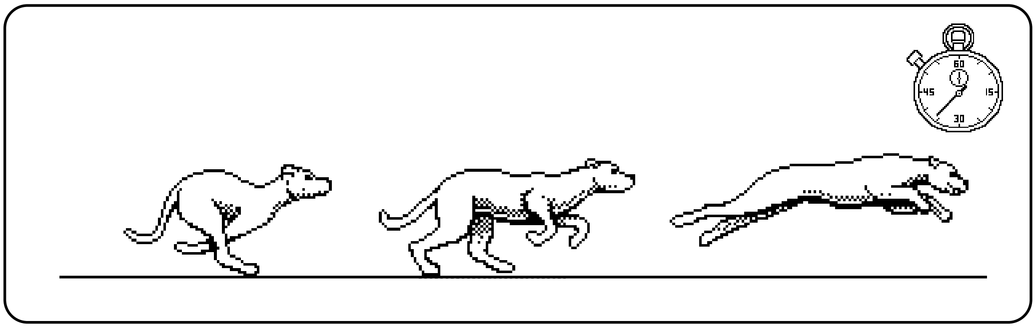
Partners: Date:

PHYSICS 100 LAB 2: CHANGING MOTION



*A **cheetah** can accelerate from 0 to 50 miles per hour in 6.4 seconds.*

Encyclopedia of the Animal World

*A **Jaguar** automobile can accelerate from 0 to 50 miles per hour in 6.1 seconds.*

World Cars

OBJECTIVES

- To discover how and when objects accelerate
- To understand the meaning of acceleration, its magnitude and direction
- To discover the relationship between velocity and acceleration graphs
- To learn how to represent velocity and acceleration using vectors
- To learn how to find average acceleration from acceleration graphs
- To learn how to calculate average acceleration from velocity graphs

OVERVIEW

When the velocity of an object is changing, it is also important to know how it is changing. The rate of change of velocity with respect to time is known as the *acceleration*.

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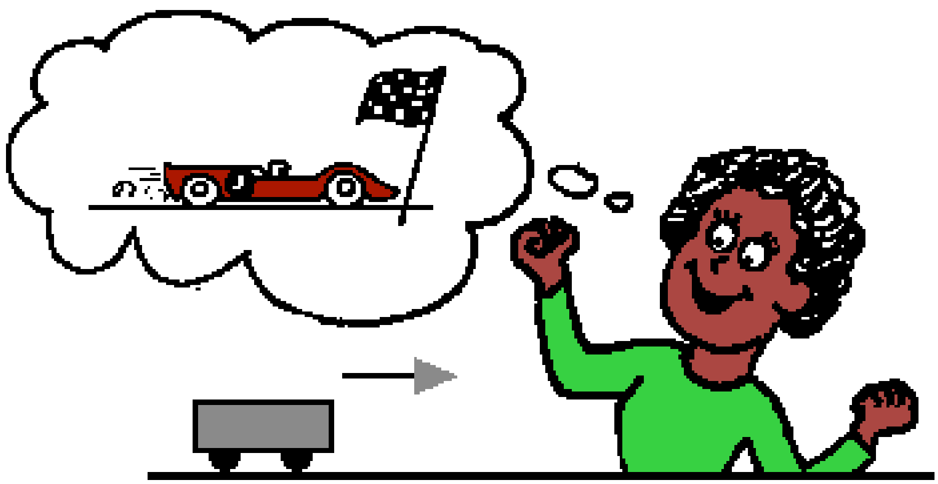
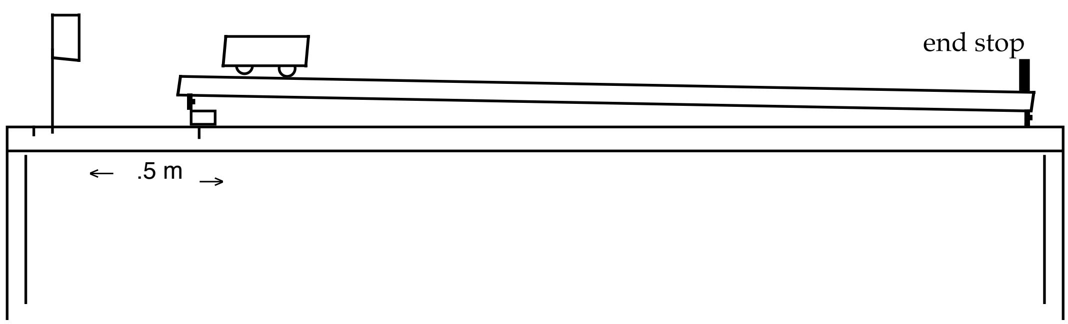
IN ORDER TO GET A FEELING FOR ACCELERATION, IT IS HELPFUL TO CREATE AND LEARN TO INTERPRET VELOCITY-TIME AND ACCELERATION-TIME GRAPHS FOR SOME RELATIVELY SIMPLE MOTIONS OF A CART ON A SMOOTH RAMP OR OTHER LEVEL SURFACE. YOU WILL BE OBSERVING THE CART WITH THE MOTION DETECTOR AS IT MOVES WITH ITS VELOCITY CHANGING AT A CONSTANT RATE. INVESTIGATION 1: VELOCITY AND ACCELERATION GRAPHS

In this investigation you will be asked to predict and observe the shapes of velocity-time and acceleration-time graphs of a cart (or toy car) moving along a smooth ramp which is slightly tilted. You will focus on cart motions with a steadily increasing velocity.

Activity 1-1: Speeding Up



1. Set up the cart on the ramp, with the ramp tilted by placing a small block under the end nearest the motion detector.



2. Open the experiment **L2A1-1 (Speeding Up)** to display a two graph layout with **Position** from **0** to **2.0** m and **Velocity** from **-1.0** to **1.0** m/sec for a time interval of **3.0** sec, as shown on the next page.

   Use a position graph to make sure that the detector can "see" the cart all the way to the end of the ramp. You may need to tilt the detector up slightly.

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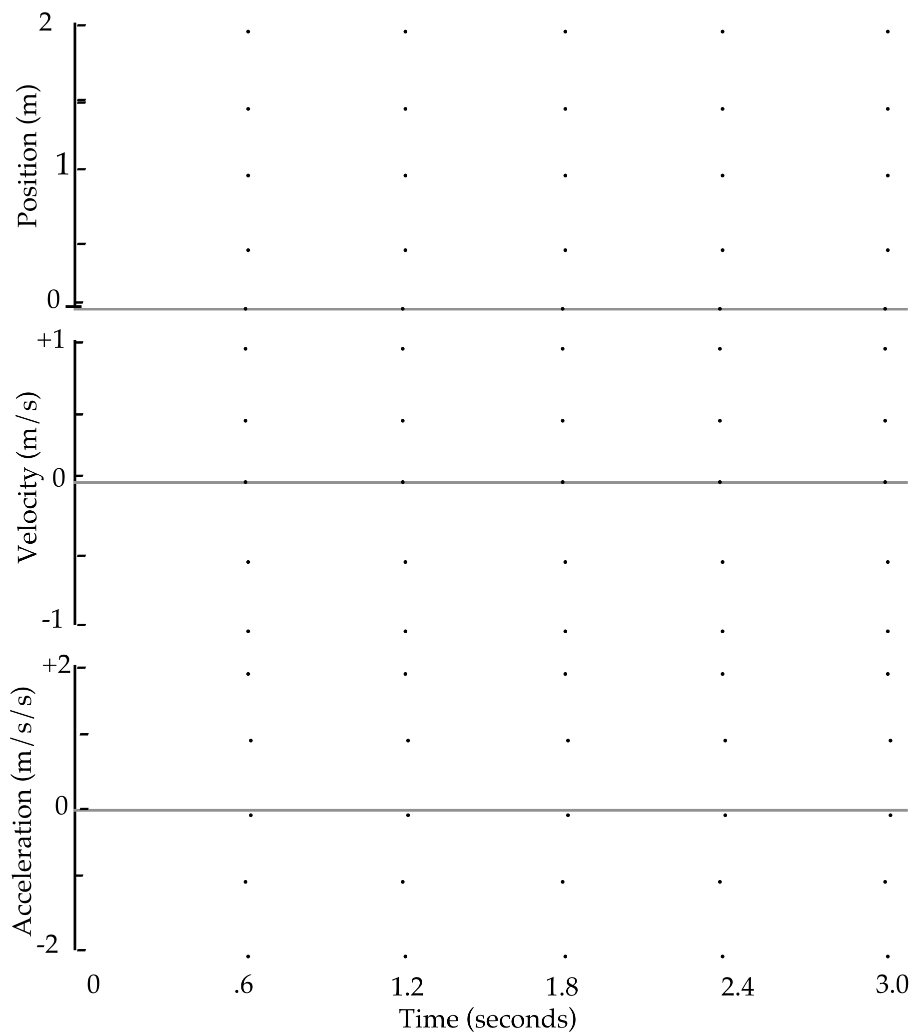
3. Hold the cart, press **Collect**, and when you hear the clicks of the motion detector, release the cart from rest. Do not put your hand between the cart and the detector. **Be sure to stop the cart before it hits the end stop.**

   Repeat, if necessary, until you get a nice set of graphs.

   Change the position and velocity scales if necessary so that the graphs fill the axes. Store the data by selecting **Store Latest Run** under **Experiment**. Then click on **Data-> Data Set Options->Run1** to change the name of the data set to **SpeedUp1_xxx** where xxx is your initials. Each person in this group should have their own data set. Hide your saved data set by selecting your data set under **Data->Hide Data Sets** before your partner repeats the same experiment. This way your and your partner's graphs will not overlap.

   Sketch your position and velocity graphs neatly on the axes which follow. Label the graphs "*Speeding Up 1*." (Ignore the acceleration axes for now.)

PREDICTION AND FINAL RESULTS



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Question 1-1: What feature of your velocity graph signifies that the motion was *away* from the detector?

Question 1-2: What feature of your velocity graph signifies that the cart was *speeding up*? How would a graph of motion with a constant velocity differ?

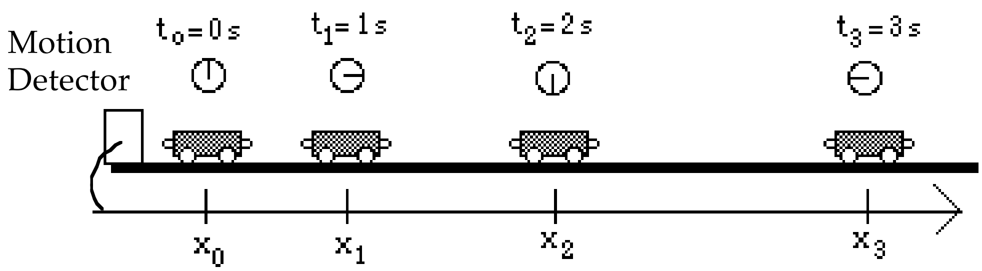
4. Change the **Position** display to **Acceleration** by clicking on the Position axis and scrolling to Acceleration. Adjust the acceleration scale so that your graph fills the axes. Sketch your graph on the acceleration axes above, and label it "*Speeding Up 1*."

Question 1-4: During the time that the cart is speeding up, is the acceleration positive or negative? How does *speeding up* while moving *away* from the detector 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 1-5: How does the velocity vary in time as the cart speeds up? Does it increase at a steady rate or in some other way?

Question 1-6: How does the acceleration vary in time as the cart speeds up? Is this what you expect based on the velocity graph? Explain.

Question 1-7: The diagram below shows the positions of the cart at equal time intervals.



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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 and speeding up.

Question 1-8: Show below how you would find the vector representing the change in velocity between the times 1 sec and 2 sec in the diagram above. (Hint: remember that the change in velocity is the final velocity minus the initial velocity, and the vector difference is the same as the sum of one vector and the negative of the other vector.)

Based on the direction of this vector and the direction of the positive x-axis, what is the sign of the acceleration? Does this agree with your answer to Question 1-4?

Activity 1-2 Speeding Up More

Prediction 1-1: Suppose that you accelerate the cart at a faster rate. How would your velocity and acceleration graphs be different? Sketch your predictions with dashed or different color lines on the axes on page 2-5.

1. Test your predictions. Make velocity and acceleration graphs. This time tilt the track a little more.

   Repeat if necessary to get nice graphs. When you get a nice set of data, save it as **SpeedUp2_xxx**.
2. Sketch your velocity and acceleration graphs with solid or different color lines on the axes on page 2-5, or print the graphs and affix them over the axes. Be sure that the graphs are labeled "*Speeding Up 1*" and "*Speeding Up 2*."

Question 1-9: Did the shapes of your velocity and acceleration graphs agree with your predictions? How is the magnitude (size) of acceleration represented on a velocity-time graph?

Question 1-10: How is the magnitude (size) of acceleration represented on an acceleration-time graph?

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INVESTIGATION 2: MEASURING ACCELERATION

In this investigation you will examine more quantitatively the motion of an accelerating cart. This analysis will be quantitative in the sense that your results will consist of numbers. You will determine the cart's acceleration from your velocity-time graph and compare it to the acceleration read from the acceleration-time graph.

You will need the Logger Pro software and the data sets you saved from Investigation 1.

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

1. Show the data for the cart accelerated along the ramp with the least tilt (Investigation 1, Activity 1-1) by selecting **Data->Show Data Set->SpeedUp1_xxx**. Make sure you select your OWN data set.

   Display velocity and acceleration, and adjust the axes if necessary.
2. Find the average acceleration of the cart from your acceleration graph. Click on **Page 1** icon near the top left corner and select Page 2. Record a number of values (say ten) of acceleration (from your OWN data set), which are equally spaced. (Only use values from the portion of the graph after the cart was released and before the cart was stopped.)

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

   Average acceleration (mean): __________m/s^2

Comment: Average acceleration during a particular time period is defined as the average rate of change of velocity with respect to time--the change in velocity divided by the change in time. 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-time graph is also the (average) acceleration of the object.

3. Calculate the slope of your velocity graph. From the same table read the velocity and time values for two typical points. (For a more accurate answer, use two points as far apart in time as possible but still during the time the cart

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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 (sec)	
Average acceleration (m/s^2)	

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

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

Activity 2-2: Speeding Up More

1. Show the data for the cart accelerated along the ramp with more tilt (Investigation 1, Activity 1-2) from your **SpeedUp2_xxx** data set. Display velocity and acceleration.
2. Read acceleration values from the table, and find the average acceleration of the cart from your acceleration graph.

Acceleration Values (m/s^2)			
1		6	

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2		7	
3		8	
4		9	
5		10	

Average acceleration (mean): __________ m/s^2

3. Calculate the average acceleration from your velocity graph. 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 (sec)	
Average acceleration (m/s^2)	

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

Question 2-4: Compare this average acceleration to that with less tilt (Activity 2-1). Which is larger? Is this what you expected?

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INVESTIGATION 3: SLOWING DOWN AND SPEEDING UP

In this investigation you will look at a cart (or toy car) moving along a ramp or other level surface *and slowing down*. A car driving down a road and being brought to rest by applying the brakes is a good example of this type of motion.

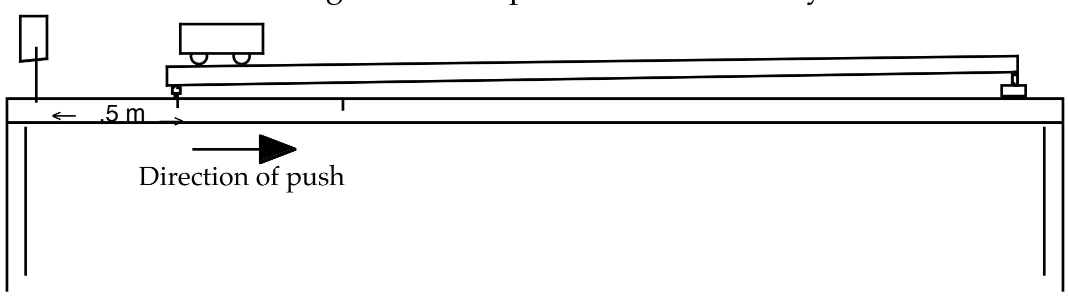
Later you will examine the motion of the cart *toward* the motion detector and *speeding up*.

In both cases, we are interested in the shapes of the velocity-time and acceleration-time graphs, as well as the vectors representing velocity and acceleration.

Activity 3-1: Slowing Down

In this activity you will look at the velocity and acceleration graphs of the cart when it is moving *away from* the motion detector and *slowing down*.

1. The cart, ramp, and motion detector should be set up as in Investigation 1 except tilted the other way.



Now, when you give the cart a push away from the motion detector, it will slow down after it is released.

Prediction 3-1: If you give the cart a push away from the motion detector and release it, will the acceleration be positive, negative or zero (after it is released)?

Sketch your predictions for the velocity-time and acceleration-time graphs on the axes below.

2. Test your predictions. Open the experiment **L2A3-1 (Slowing Down)** to display the velocity-time and acceleration-time axes shown below.

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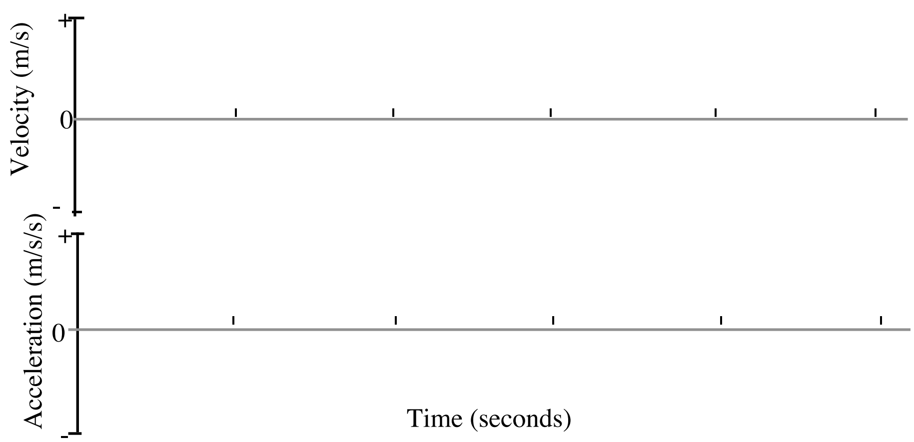
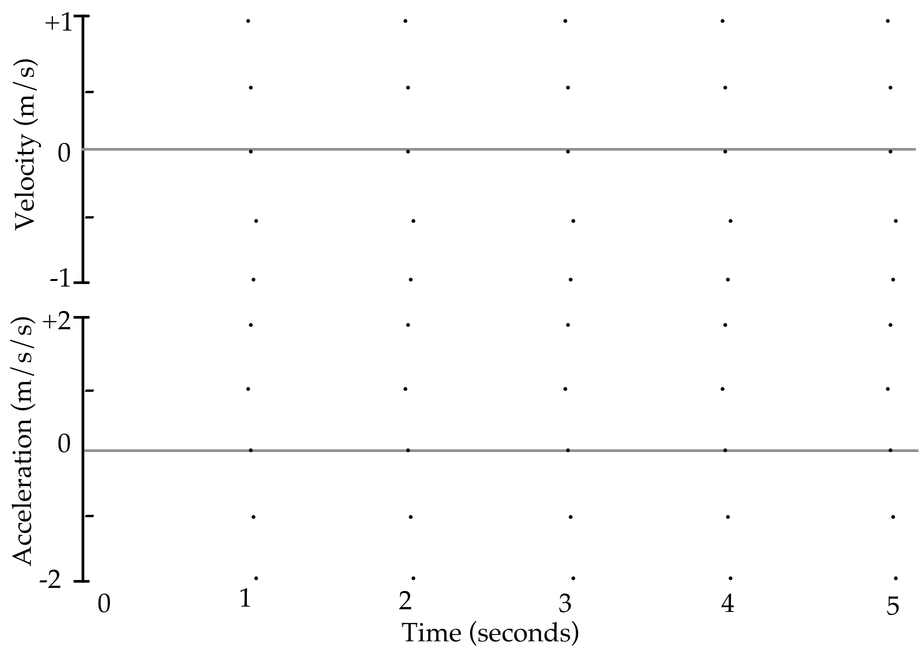
PREDICTION



FINAL RESULTS



3. Graph velocity first. **Collect** with the back of the cart near the 0.50 meter mark. When you begin to hear the clicks from the motion detector, give the cart a gentle push away from the detector so that it comes to a stop near the end of the ramp. **(Be sure that your hand is not between the cart and the detector.) Stop the cart--do not let it return toward the motion detector.**

   You may have to try a few times to get a good run. Don't forget to change the scales if this will make your graphs easier to read.

   Store the data set as **SlowingDown1_xxx**.

4. Neatly sketch your results on the axes above or print the

graphs and affix them over the axes.

Label your graphs with—

- "A" at the spot where you started pushing.
- "B" at the spot where you stopped pushing.
- "C" at the spot where the cart stopped moving.

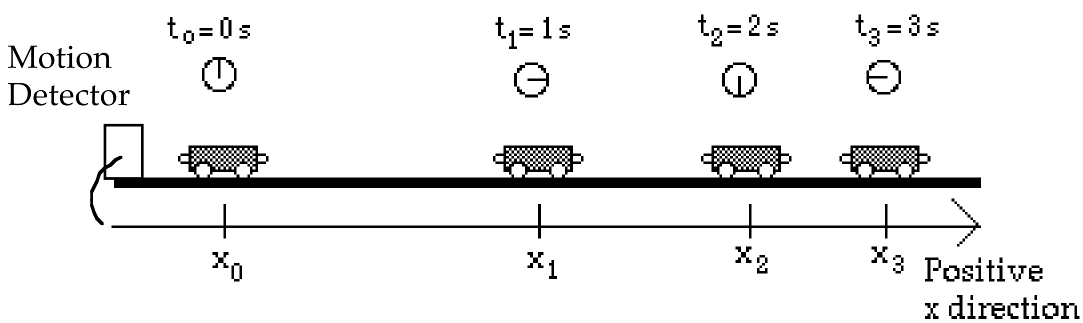
Also sketch on the same axes the velocity and acceleration graphs for *Speeding Up 2* from Activity 1-2.

Question 3-1: Did the shapes of your velocity and acceleration graphs agree with your predictions? How can you tell the sign of the acceleration from a velocity-time graph?

Question 3-2: How can you tell the sign of the acceleration from an acceleration-time graph?

Question 3-3: Is the sign of the acceleration what you predicted? How does *slowing down* while moving *away* from the detector result in this sign of acceleration? Hint: remember that acceleration is the *rate of change* of velocity with respect to time. Look at how the velocity is changing.

Question 3-4: The diagram below shows the positions of the cart at equal time intervals. (This is like overlaying 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 and slowing down.



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Question 3-5: Show below how you would find the vector representing the change in velocity between the times 1 sec and 2 sec in the diagram above. (Remember that the change in velocity is the final velocity minus the initial velocity.)

Based on the direction of this vector and the direction of the positive x-axis, what is the sign of the acceleration? Does this agree with your answer to Question 3-3?

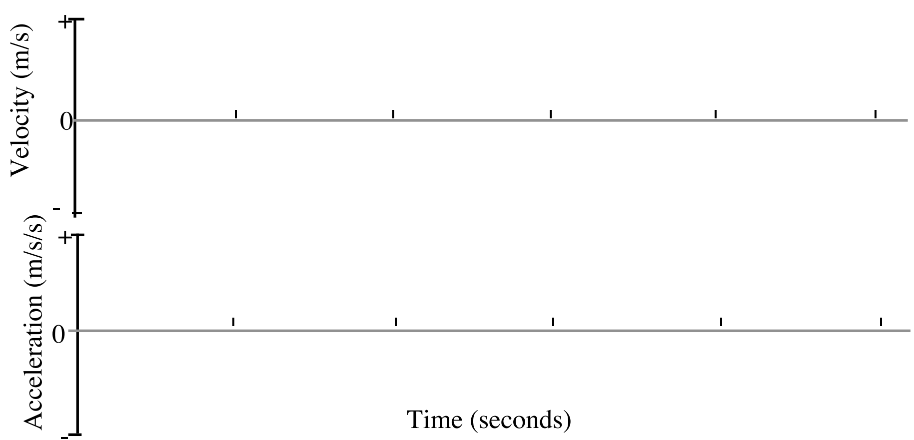
Question 3-6: Based on your observations in this activity and in the last lab, state a general rule to predict the sign and direction of the acceleration if you know the sign of the velocity (i.e. the direction of motion) and whether the object is speeding up or slowing down.

Activity 3-2 Speeding Up Toward the Motion Detector

Prediction 3-2: Suppose now that you start with the cart at the far end of the ramp, and let it speed up *towards* the motion detector. As the cart moves toward the detector and speeds up, predict the direction of the acceleration. Will the acceleration be positive or negative? (Use your general rule from Question 3-6.)

Sketch your predictions for the velocity-time and acceleration-time graphs on the axes which follow.

PREDICTION



1. Test your predictions**.** First clear any previous graphs. Graph the cart moving *towards* the detector and *speeding up.* Graph velocity first. When you hear the clicks from the

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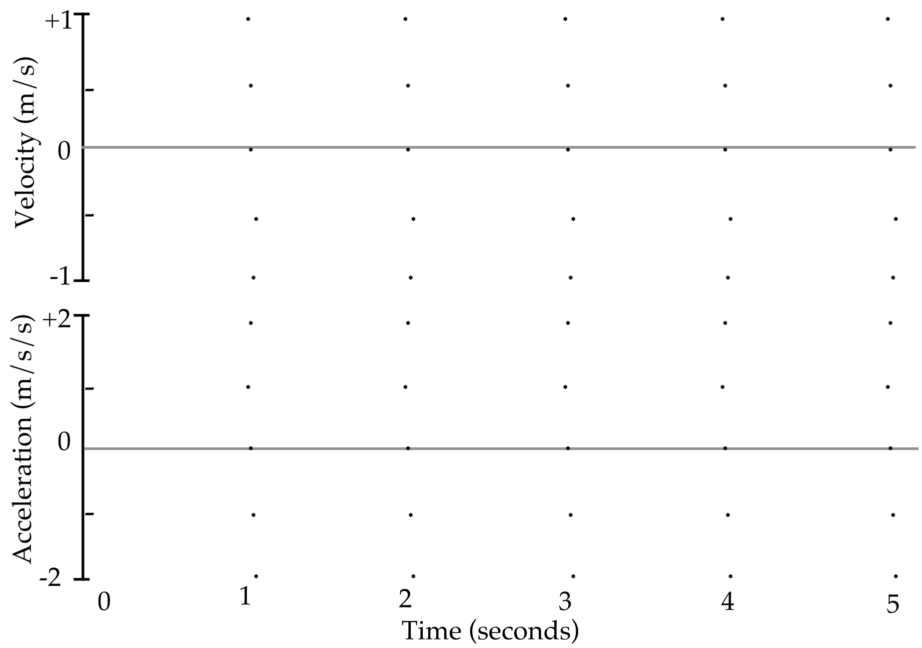
motion detector, release the cart from rest from the far end of the ramp. **(Be sure that your hand is not between the cart and the detector.) Stop the cart when it reaches the 0.5 meter line.**

2. Sketch these graphs on the velocity and acceleration axes below. Label these graphs as "*Speeding Up Moving Toward*."

FINAL RESULTS



Question 3-7: How does your velocity graph show that the cart was moving *toward* the detector?

Question 3-8: During the time that the cart was speeding up, is the acceleration positive or negative? Does this agree with your prediction? Explain how *speeding up* while moving *toward* the detector results in this sign of acceleration. Hint: look at how the velocity is changing.

Question 3-9: The diagram below shows the positions 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 toward the motion detector and speeding up.

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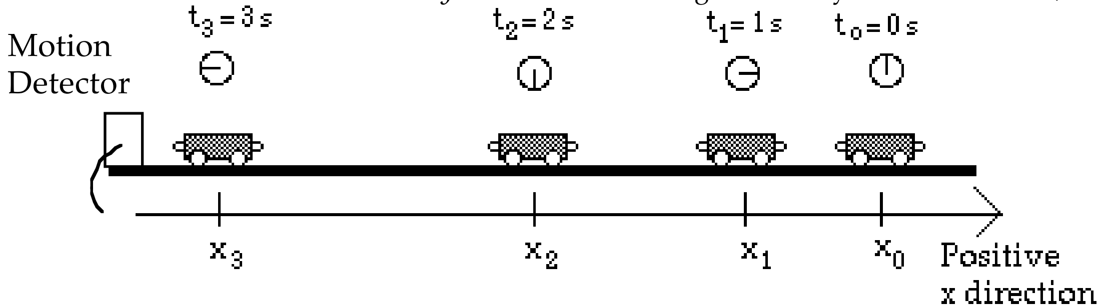

Question 3-10: In the space below, show how you would find the vector representing the change in velocity between the times 1 sec and 2 sec in the diagram above. Based on the direction of this vector and the direction of the positive x-axis, what is the sign of the acceleration? Does this agree with your answer to Question 3-8?

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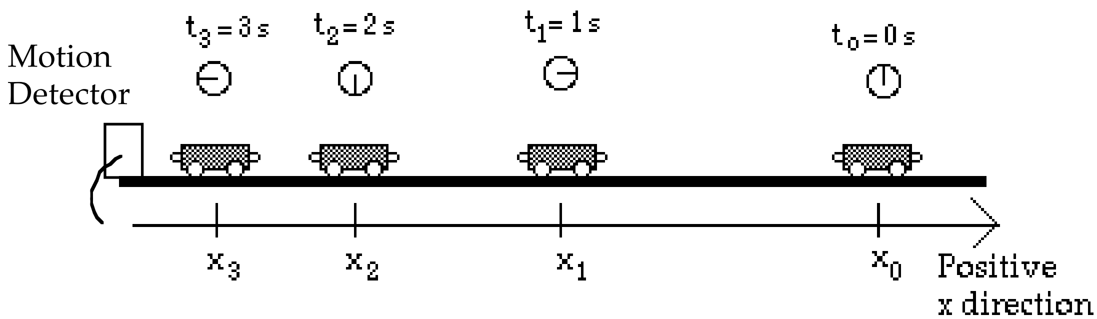
Question 3-11: Was your general rule in Question 3-6 correct? If not, modify it and restate it here.

Question 3-12: There is one more possible combination of velocity and acceleration for the cart, moving *toward* the detector and *slowing down*. Use your general rule to predict the direction and sign of the acceleration in this case. Explain why the acceleration should have this direction and this sign in terms of the sign of the velocity and how the velocity is changing.

Question 3-13: The diagram below shows the positions of the cart at equal time intervals for the motion described in Question 3-12. 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 toward the motion detector and slowing down.



Question 3-14: In the space below, show how you would find the vector representing the change in velocity between the times 1 sec and 2 sec in the diagram above. Based on the direction of this vector and the direction of the positive x-axis, what is the sign of the acceleration? Does this agree with your answer to Question 3-12?

Activity 3-3: 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 is its velocity changing? What is its acceleration?

The setup should be as shown below--the same as before.

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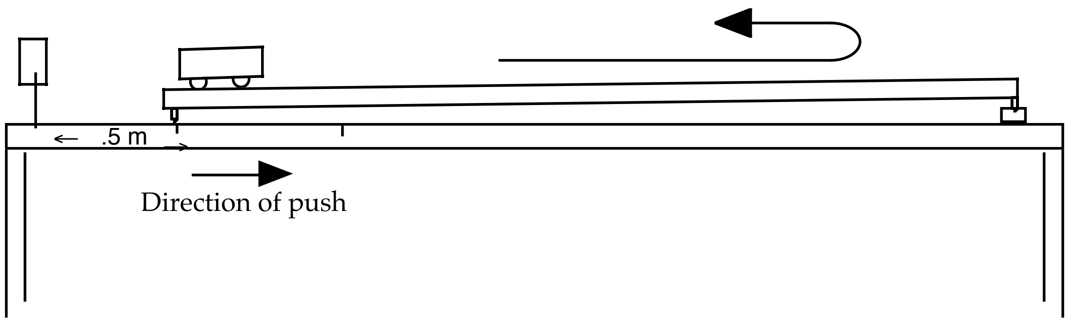


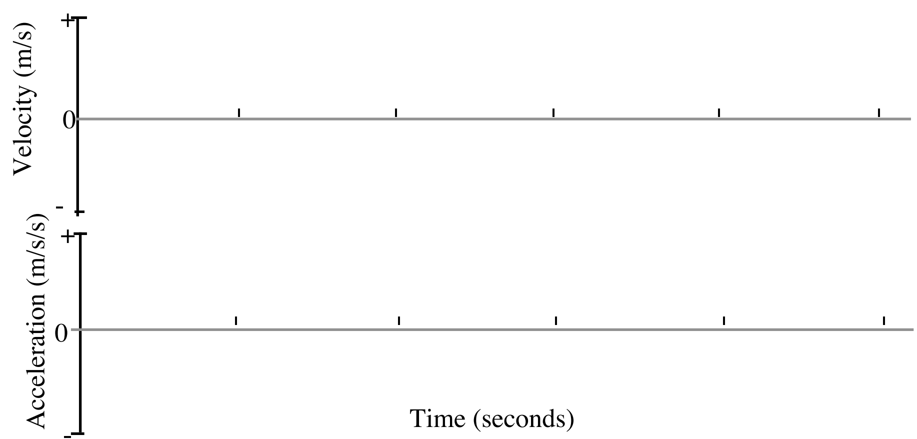
Prediction 3-3: Give the cart a push *away* from the motion detector. It moves away, slows down, reverses direction and then moves back toward the detector. Try it without using the motion detector! **Be sure to stop the cart before it hits the motion detector.**

For each part of the motion--*away from the detector, at the turning point and toward the detector*, 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 on the axes which follow your predictions of the velocity-time and acceleration-time graphs of this entire motion.

PREDICTION



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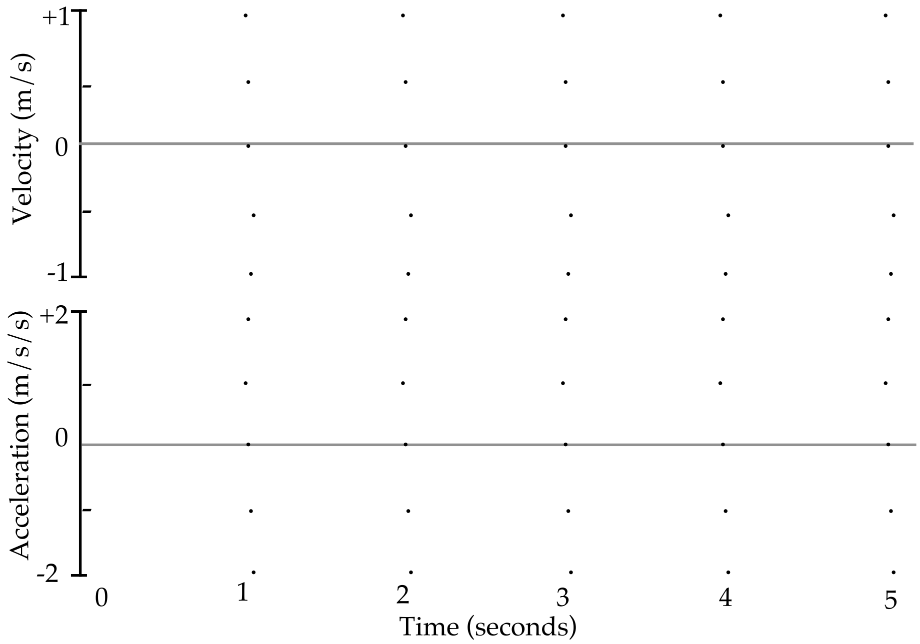
1. Test your predictions. Set up to graph velocity and acceleration on the following graph axes. (Open the experiment **L2A3-1 (Slowing Down)** if it is not already opened.)

FINAL RESULTS



2. Start with the back of the cart near the 0.5 meter mark. When you begin to hear the clicks from the motion detector, give the cart a gentle push away from the detector so that it travels at least one meter, slows down, and then reverses its direction and moves toward the detector. (Be sure that your hand is not between the cart and the detector.)

   Be sure to stop the cart by the 0.5 meter line, keep it from hitting the motion detector.

   You may have to try a few times to get a good round trip. Don't forget to change the scales if this will make your graphs clearer.
3. When you get a good round trip, sketch both graphs on the axes above.

Question 3-15: Label *both* graphs with—

- "A" where the cart started being pushed.
- "B" where the push ended (where your hand left the cart).
- "C" where the cart reached its turning point (and was about to reverse direction).
- "D" where the you stopped the cart.

Explain how you know where each of these points is.

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Question 3-16: Did the cart "stop"? (Hint: look at the velocity graph. What was the velocity of the cart at its turning point?) Does this agree with your prediction? How much time did it spend at zero velocity before it started back toward the detector? Explain.

Question 3-17: According to your acceleration graph, what is the acceleration at the instant the cart reaches its turning point? Is it positive, negative or zero? Is it any different from the acceleration during the rest of the motion? Does this agree with your prediction?

Question 3-18: Explain the observed sign of the acceleration at the tuning point. (Hint: remember that acceleration is the *rate of change* of velocity. When the cart is at its turning point, what will its velocity be in the next instant? Will it be positive or negative?)

Question 3-19: On the way back toward the detector, is there any difference between these velocity and acceleration graphs and the ones in **Data B** which were the result of the cart rolling back from rest (Activity 3-2)? Explain.

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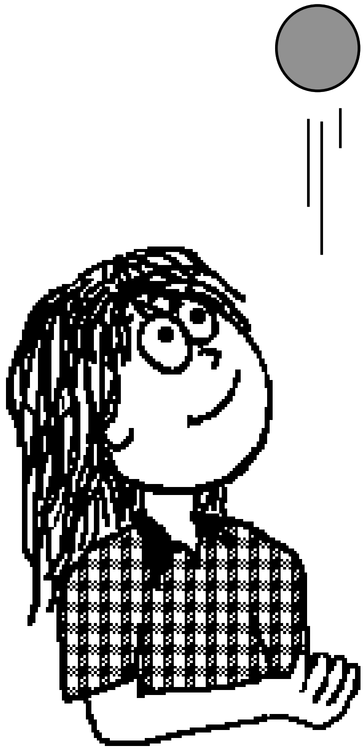

Challenge: You throw a ball up into the air. It moves upward, reaches its highest point and then moves back down toward your hand. Assuming that upward is the positive direction, indicate in the table that follows whether the velocity is positive, zero or negative during each of the three parts of the motion. Also indicate if the acceleration is positive, zero or negative. Hint: remember that to find the acceleration, you must look at the *change in* velocity.

	Moving Up--<u>after release</u>	At Highest Point	Moving Down
Velocity			
Acceleration			

Question 3-20: In what ways is the motion of the ball similar to the motion of the cart which you just observed?

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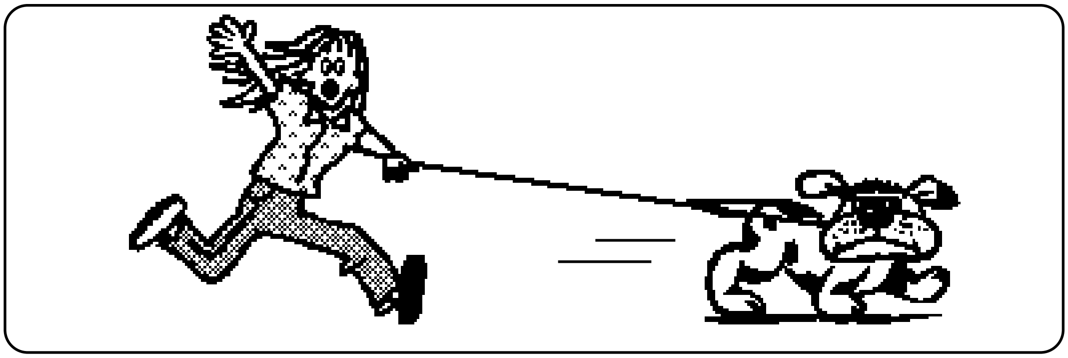
Physics 100 Lab: Changes in Velocity with a Constant Force*



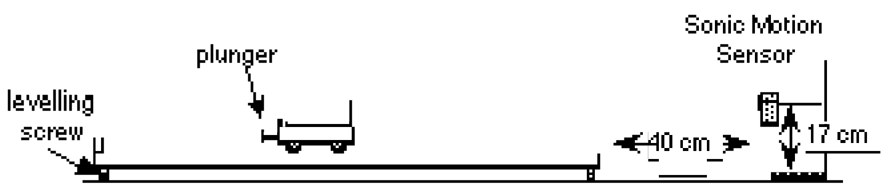
Introduction

We know qualitatively from everyday experience that we must apply a force to move an object from rest or to change its velocity while it is moving, but we are not so sure of the quantitative relation between the velocity changes and the force we apply. We can investigate this relation with the sonic motion detector, a cart on a track and a small spring.

The cart, loaded with iron bars and running on wheels, can be pulled forward with a constant force by hand. To make sure the force is constant, we apply it through a spring which can be kept stretched at a constant length as the cart is pulled along.

What to do

1.The track and motion detector should already be set up for you - check; if they are not, align the motion detector with the track so that it is about 40 cm from the track and about 21cm above the table top. Aim the detector down the track so that it can follow the motion of a cart as it moves on the track.



2. Make sure the track is clean (no eraser crumbs, etc.), place a cart on the track and load it with two iron bars. If the track is not level the cart will start to roll one way or the other. You can adjust the levelling screw at one end of the track until the track seems level.

3. Turn on the computer open **Lab#3,** then opem **L3#1 (Force and acceleration)** from the menu. You should see a blank graph with axes velocity and time. Put the cart on the track about 50 cm from the motion detector. Click the mouse on **Start** and give the cart a shove. The computer should graph its velocity as it moves away. We have mounted a cardboard reflector on the cart to help the detector track it. If the graph has erratic glitches in it or if it doesn't seem to follow the cart's motion, try adjusting the alignment of the motion

---

* Adapted from PSSC Physics Laboratory Manual, 2nd ed.

detector with the track. Call an instructor for help if you need it. (It will graph both position and velocity.)

4. Before making runs to find how the velocity changes with a constant force, you should be sure the cart runs with a nearly constant speed when you do not pull it. Make several graphs of velocity vs. time, giving the cart different initial pushes. Look carefully at the graphs.

Is the velocity more uniform when the cart moves slowly or when it moves rapidly?--

5. Now you can study the effect of a constant pull on the motion of the cart. Attach one end of the homemade spring scale to the cart loaded with two bars. Hook it on the end with the plunger so that the collision with the track's bumper will be softened by the plunger. While your partner holds the cart, extend the spring along the track until it stretches about 1.5 cm. (There should be a mark on the case. The spring, extended this amount will be your standard unit of force--call it a "sprang.") Your partner starts the timing and a few seconds later, on signal, releases the cart. You move forward, pulling the cart while keeping the spring stretched to the 1.5 cm mark. You will find it worthwhile to try a few practice runs.

What did you have to do to maintain a constant stretch of the spring immediately after your partner released the cart?--

How would you describe the magnitude of the velocity as you maintain a constant force on the moving cart?--

6. The graph should show an increase in velocity as you pull the cart. Select **Page 2** and read from the table two velocities for two times during the time you pulled the cart. Choose points as widely spaced as possible but only analyze that portion of the run where you are reasonably sure the force applied was constant. (You may have slacked off as the cart neared the end of the track.) Record the times and velocities below. Repeat for a cart loaded with one bar and then, no bar.

Provide the data in the following table:

Analysis of velocity change with cart loaded with 2 bars

t (sec)	v (m/sec)

Δt =---------------- Δv =------------------

$a_{av} = \frac{\Delta v}{\Delta t}$ = -----

Analysis of velocity change with cart loaded with 1 bar

t (sec)	v (m/sec)

$\Delta t =$ ---------------- $\Delta v =$ ------------------

$$a_{av} = \frac{\Delta v}{\Delta t} = \ldots..$$

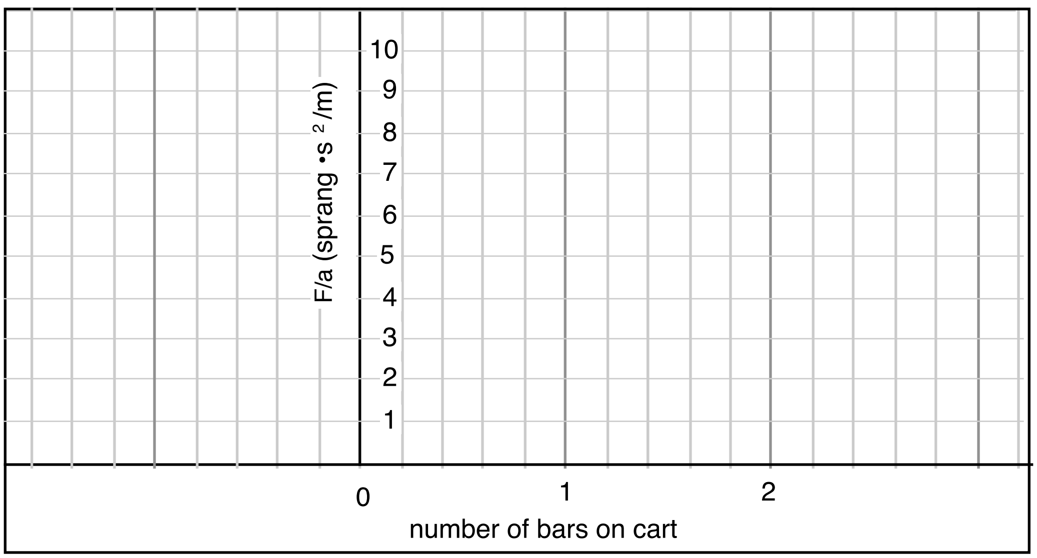
Analysis of velocity change with cart loaded with no bar

t (sec)	v (m/sec)

$\Delta t =$ ---------------- $\Delta v =$ ------------------

$$a_{av} = \frac{\Delta v}{\Delta t} = \ldots.$$

6. Plot $\frac{\text{force}}{\text{acceleration}}$ vs. number of bars on the next graph.



How does the acceleration vary with the mass on the cart? ----------------------------
----

Can you determine the mass of the cart from this graph? ------------------------------

If yes, do it. ---

If you have time....

Try pulling the cart with two springs in parallel, so that each spring is stretched the same amount. Measure the change in velocity. How do two nearly equal forces affect the acceleration when they are applied in the same direction?

Try pulling the cart with the two springs opposed so that the forces are in opposite directions. What is the affect on the velocity of the cart?

Challenge: Stop a moving cart by blowing on it.

First have your partner give the cart a good shove down the track and watch it as it hits the bumper on the end. Your task will be to stop the motion of the cart by blowing on it through a soda straw. Decide at what point you will start blowing on the cart.

Start blowing at ________________m

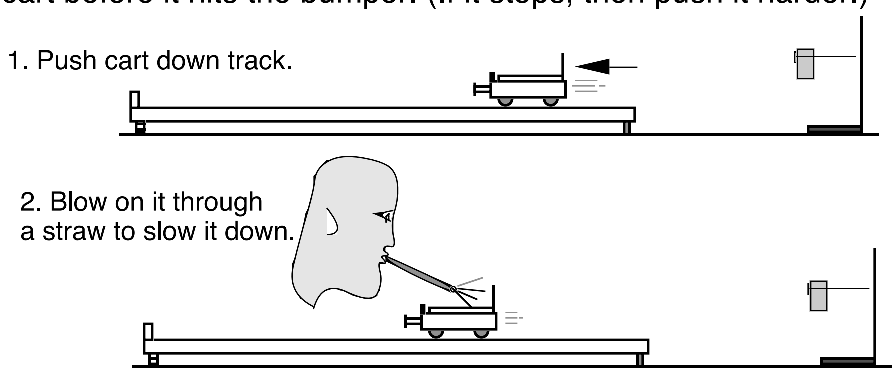
Predict where you will be able to stop the motion of the cart.

Cart will stop at _______________ m.

Now, here you go...

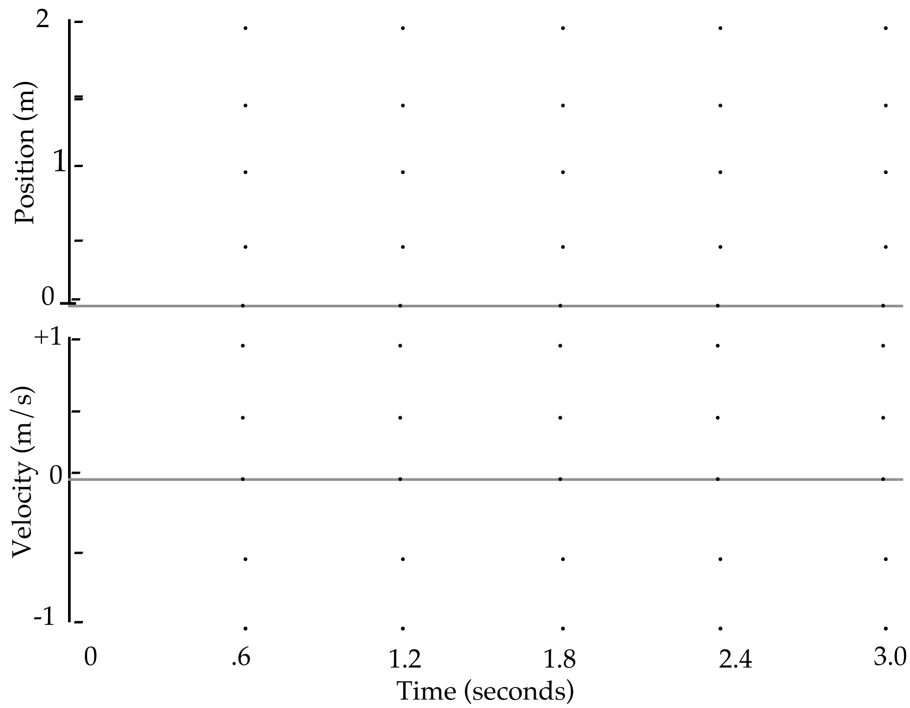
0. Set up the sonic motion detector 40 cm from the end of the track and about 17 cm above it. Open Logger Pro by clicking on **Lab#3,** then open **L3 #1**.

1. Start the timing and push the cart away from the motion detector. The cart should slow slightly as it moves because of friction, but not enough to stop the cart before it hits the bumper. (If it stops, then push it harder.)



2. After it has moved the desired distance, start blowing on the cart through the soda straw to slow it down. Try to bring it to a stop and, if you can, reverse its direction.

3. Sketch the position-time graph and the velocity-time graph and indicate the time and position at which you started blowing on the cart, and the time and position at which you stopped the cart. Also point out at which point on the graph the cart started to change direction (if you could blow that long).



While you were blowing on the cart, the force was in the direction opposite to that of the motion.

How long, in seconds, did you have to blow on the cart to bring it to a stop?----------------

How far did the cart travel before it stopped after you started blowing? ------------- m.

How does this last number compare with your prediction?

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Partners:_____________________________ Date:___________________

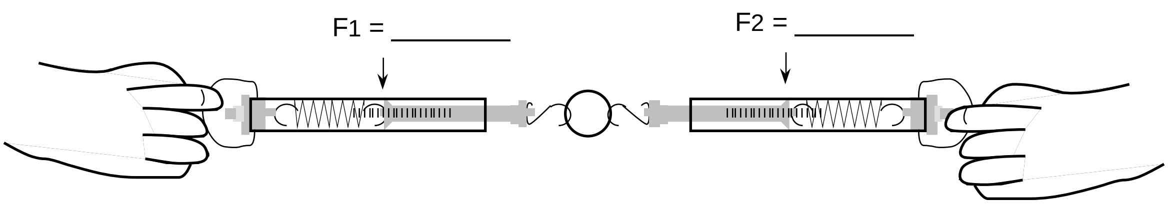
Physics 100 Lab: Forces in Equilibrium

Part 1: Forces in a straight line

Introduction

We usually think that when a force is applied to an object, its motion changes. But objects at rest may also have forces acting on them. For example, in a tug-of-war where both teams are equally matched, the forces on both ends of the rope are equal and the rope does not move. In this project, you will study forces which balance each other, or are *in equlibrium.* You will also find the condition necessary for equilibrium.

What to do

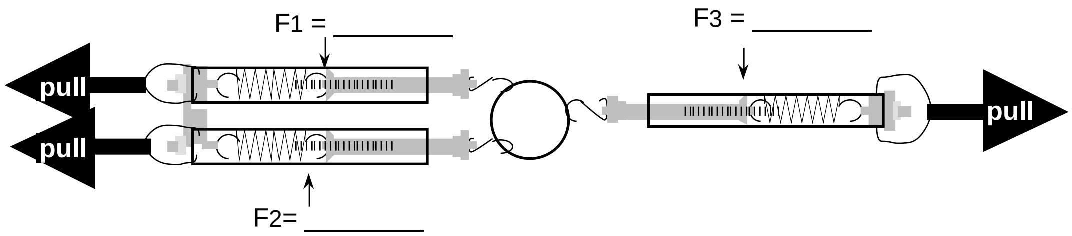


Get two similar spring scales. Hook both scales on the ring and gently pull on each in opposite directions as shown. Record the force exerted by each scale on the ring which connects them. (Use the N scale.)

Draw a force-vector diagram to scale.

Find the sum of the two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ by adding the vectors tip to tail.

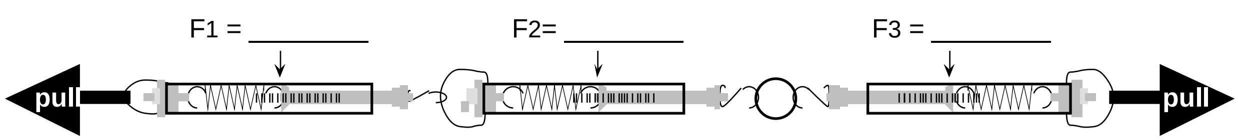
Place another spring scale parallel to one of the others as shown.
Repeat the experiment measuring the three forces.



Draw a vector diagram showing $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$.

Find the vector sum of forces. What is the condition necessary for equilibrium?

Connect two springs in series to one side of the ring as shown. Balance their force with one spring on the other side. Measure the three forces.



Explain the result you get. Why is it different from the parallel arrangement?

Part 2: 2 Dimensions

Introduction

In order to analyse the forces in two dimensions one must record the angle of the force as well as its magnitude. In the following exercises you will be given a paper protractor to guide in applying the forces in specific directions or to help measure the angle of an arbitrary force. The condition for equilibrium for the two dimensional tug-of-war is very similar to that for one dimension. Can you see that the one dimensional force pull is a special case of the two dimensional one? Can you see how the two dimensional case can be generalized to three dimensions?

What to do

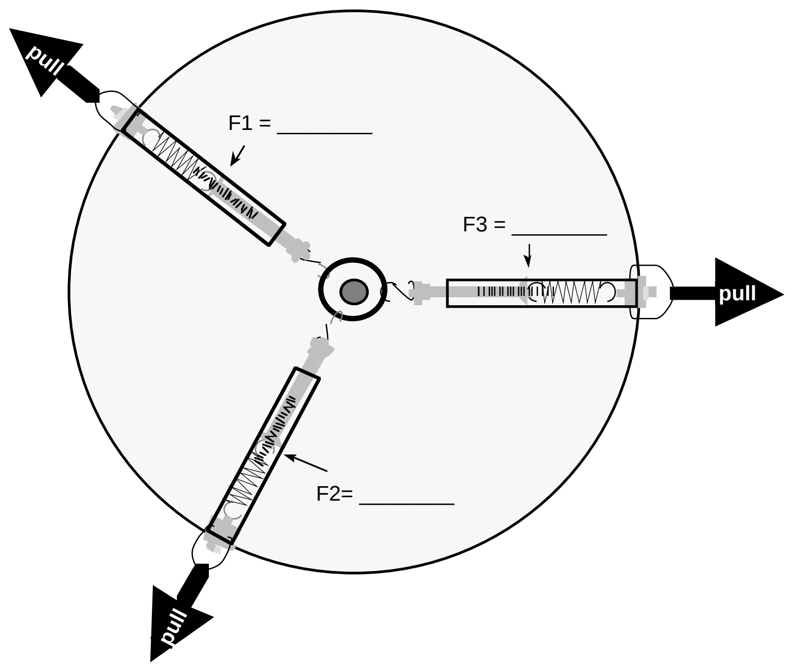
Push the center of the paper protractor on to the spindle

Place a metal ring on the center and pull outward on it with three similar spring scales along the directions of the grey lines.

As you pull the ring and keep it centered, read the forces on the spring scales in N.

Draw vectors on the grey lines whose lengths in tick marks equal the forces in N. Start each vector at the center and point it outwards.

Add the vectors graphically to get the vector sum of the forces.



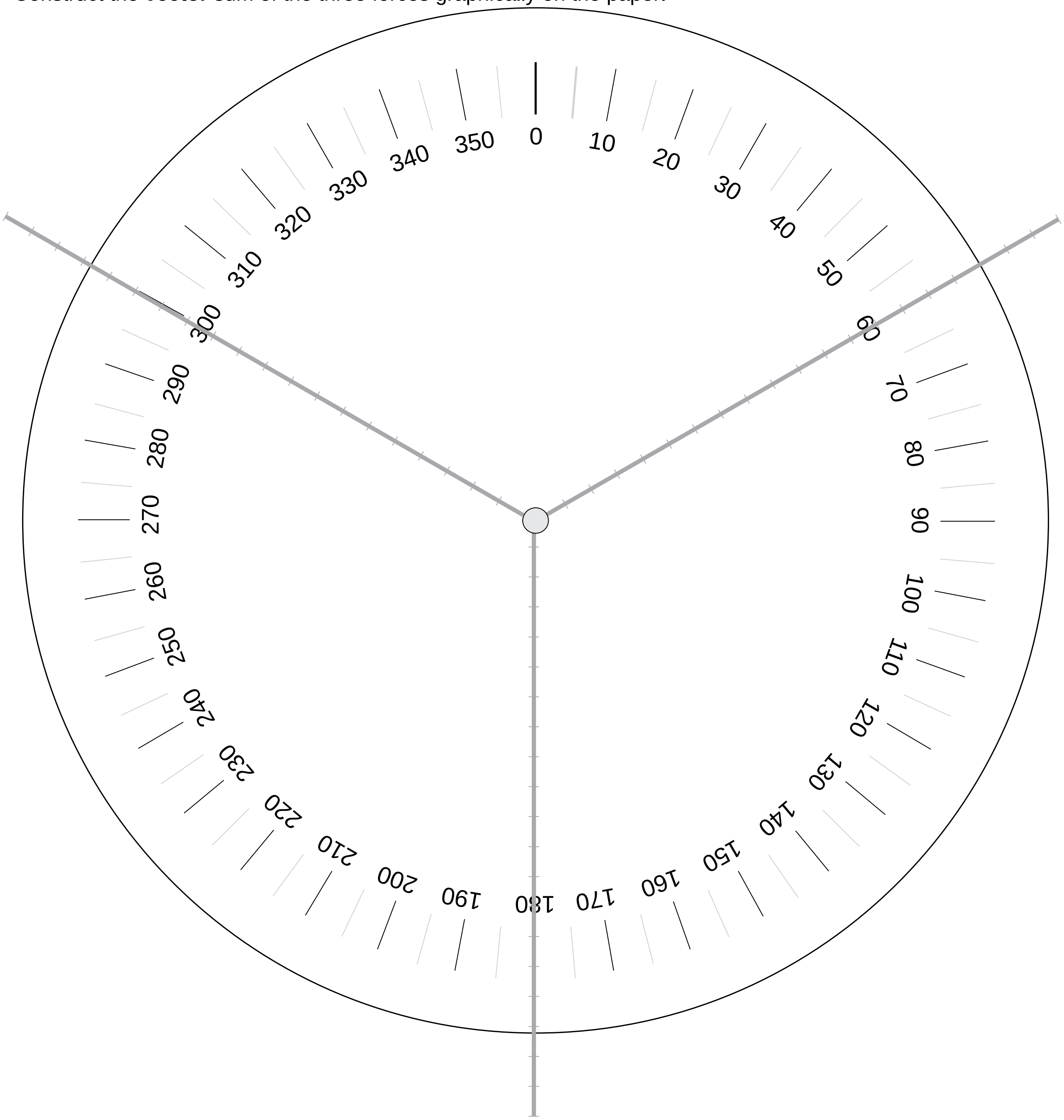
You have two paper protractors on which the angles are marked with light grey lines. These are for the first two exercises. The third paper protractor has no lines on it. Pull along any three directions you like on this one, draw the force vectors to scale, and find the vector sum of forces.

Name_________________________Sec:____ Last 2 Digits of St# ___
Partners:_________________________ Date:_____________

Exercise 1: Forces at equal angles

Instructions:

- Push the center of the paper protractor on to the spindle.
- Place a metal ring on the center and pull outward on it with three spring scales along the directions of the grey lines.
- As you pull the ring, keep it centered, not touching the spindle. Read the force on the three scales in N.
- Draw vectors on the grey lines whose lengths in tick marks represent the forces N. Start the tail of the vectors at the center and point outwards.
- Construct the **vector** sum of the three forces graphically on the paper.



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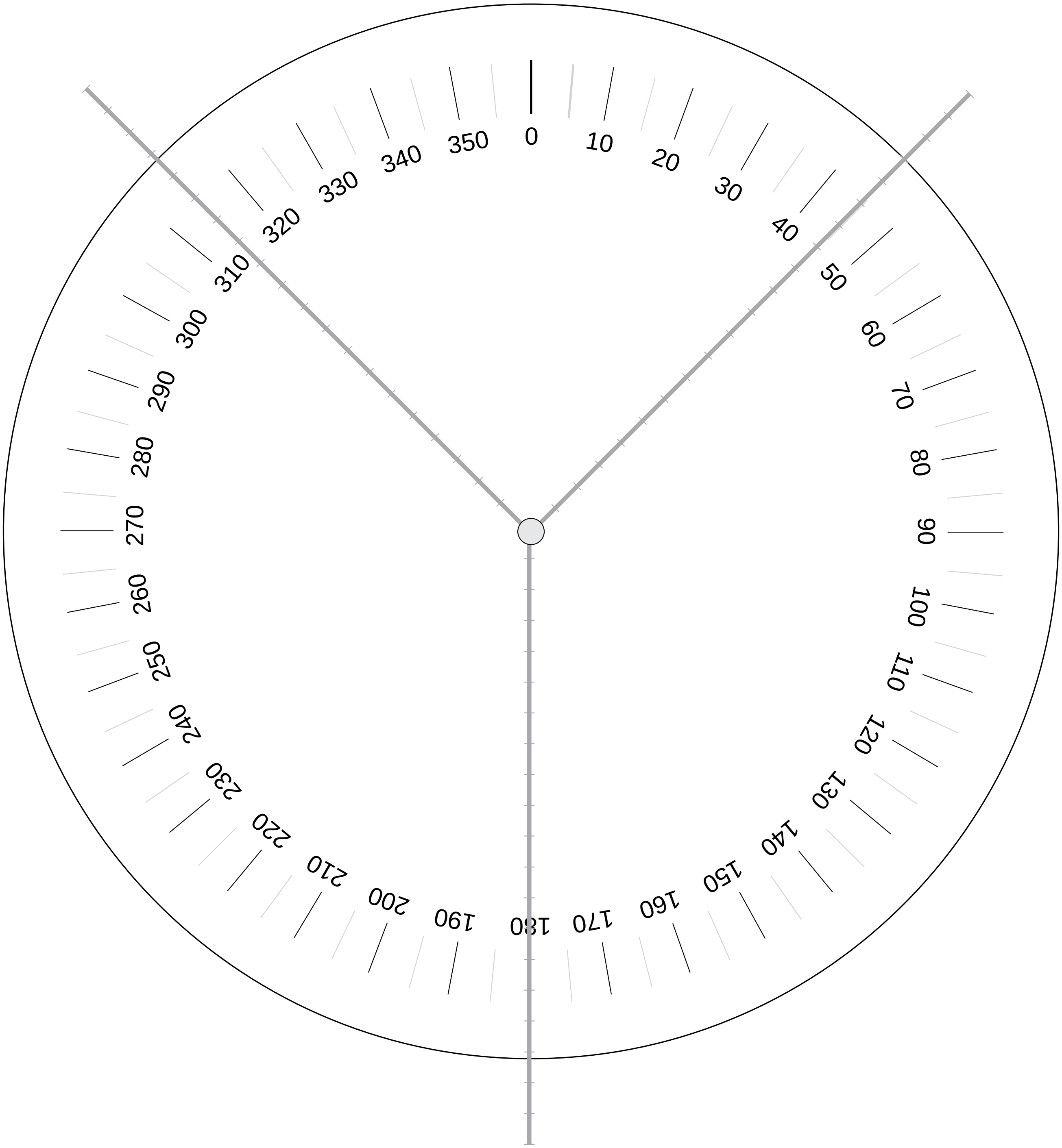
Partners:_____________________________ Date:_____________

Exercise 2: Two forces at right angles



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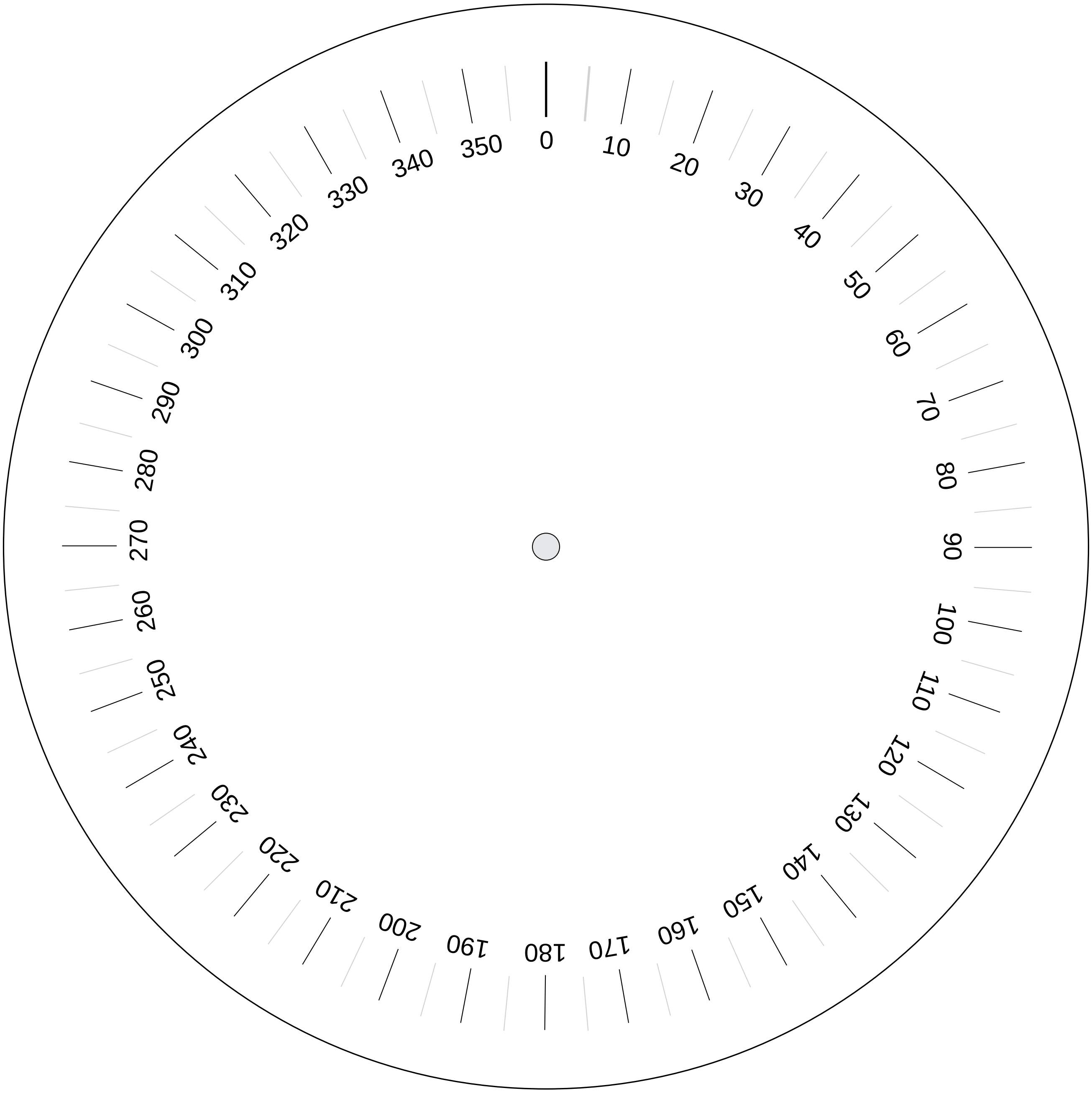
Partners:__________________________________ Date:______________

Exercise 3: Forces at arbitrary angles



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Partners:_______________________________Date:____________

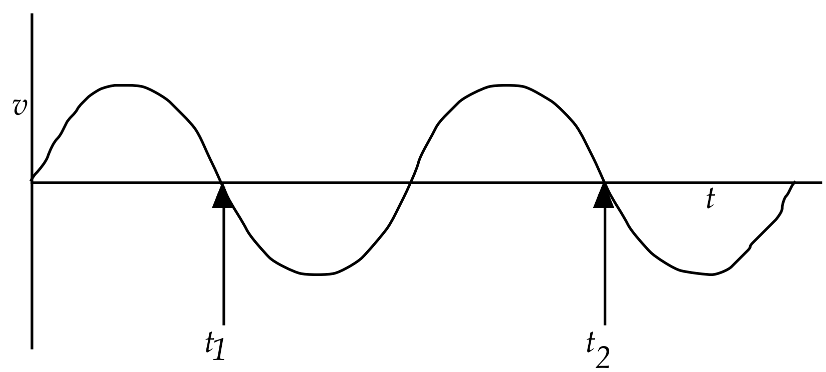
Physics 100 Lab: Simple Harmonic Motion

Harmonic motion occurs in many forms. Any system, which is slightly disturbed from a stable equilibrium, will oscillate. When the force that restores the system to equilibrium is proportional to the displacement from equilibrium, the resulting oscillations follow *Simple Harmonic Motion*. Most oscillations in nature can be approximated by simple harmonic motion. In today's experiment you will study the motion of a cart, which is attached to two springs so that it rolls back and forth in a way that is close to simple harmonic motion.

What to do

Open up the file **L5#1** from the **Lab#5** folder from the Physics 100 folder on the desktop. This should display three graphs: position, velocity and acceleration. The cart is tethered to the track by two springs and sits in equilibrium at about the middle of the track. Position the motion detector sensor about 1 m from the cart's reflector and 17 cm above the tabletop. The equilibrium position is now 1 m.

Pull the empty cart down the track about 20 cm from equilibrium and let it fly. Start data collection. You should see graphs of position; velocity and acceleration appear before your very eyes. If you see a lot of glitches (i.e., it doesn't look wavy and nice) try again.



Go to **Page 2** to read off the time for the start and end of a period, (t_1 and t_2). From this you can calculate the period T. You should try this two times to make sure your data are not aberrant. (**Note:** Adjust scales on the graph as you see fit)

Cart only: 0.5 kg

Time	trial 1	trial 2
(s)		
t_1		
t_2		
$T = t_2 - t_1$		

Now put two bars on the cart and repeat the experiment.

Cart with two masses: 1.5 kg

time	trial 1	trial 2
(s)		
t_1		
t_2		
$T = t_2 - t_1$		

Fill in the following table:

	Mass	Period, T
	(kg)	(s)
m_1	0.5	
m_2	1.5	

Is the period three time longer when the mass is three times more?_________

Now try this: take the square root of the masses.

	$\sqrt{\text{Mass}}$	Period, T
	$(\text{kg})^{1/2}$	(s)
$\sqrt{m_1}$		
$\sqrt{m_2}$		

$$\frac{\sqrt{m_1}}{\sqrt{m_2}} =$$

$$\frac{T_1}{T_2} =$$

Does the period scale with the square root of the mass?

Does the period of the oscillation depend on the amplitude of vibration? In the first trials you pulled the cart back about 20 cm. The amplitude of the vibration was about 20 cm at first, and probably decreased a little as friction took its toll.

Try an amplitude of 10 cm, empty cart. What is the period?________

When the amplitude is 20 cm, empty cart, what is the period?________

Try an amplitude of 30 cm, empty cart. What is the period?________

Compare the empty-cart periods for initial amplitudes of 10, 20 and 30 cm.

You probably did find some small variation in the period. This variation may be within the accuracy of measurement, which is about 0.2 s. What other factors might account for the variation?

How could you use this apparatus to measure the masses of objects?

Could you use this method in a weightless environment? (Assume you can find a way to keep the cart on the track.)

Is the mass you measure here the inertial mass or the gravitational mass?

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Physics 100 Lab: Projectiles and Conservation of Energy

Caution:

- **Wear Safety Glasses**

- **Don’t stick your finger into the Launcher. Use the plastic tube to load the ball.**

Part 1: Projectiles

What to do

You can predict the trajectory of a ball fired from the projectile launcher. Place four plastic hoops at evenly spaced positions along the trajectory so that the ball passes through all the hoops after it is fired.

How to do it.

You already know enough to figure out where to place the hoops. Here are some suggestions.

The launcher is clamped to the corner of your bench (see figure 1); it should be aimed such that the ball will hit the floor but not one of the benches. For the horizontal launch the plumb bob should hang over the zero degree mark.

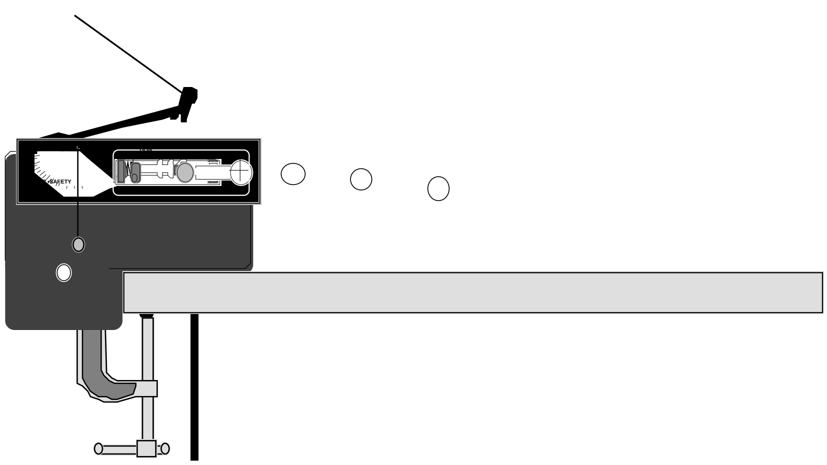

Figure 1: Horizontal launch

Place the steel ball in the barrel and push it down with the plastic pushrod until the trigger catches the piston. **DO NOT use your finger**. Push the ball again until you hear another click; the launcher is now set at the medium range. Don't use the third (long range) setting. Now launch the ball by pulling on the string.

Tape a piece of paper on the floor where the ball hit the ground. Place a piece of carbon paper on top of the paper. Tape another piece of paper to the floor directly below the launcher. Fire the ball again so that it marks the paper at the point of impact. Use a plumb bob to find and mark the point on the floor that is directly below the release point on the barrel (this is marked by a cross at the side of the launcher). Measure the horizontal distance the ball travels and the vertical distance the ball drops. (Try it several times and take the average.)

Horizontal distance from launcher to point of impact on the floor: ____________

Measure the vertical distance from the launcher to the floor: ____________

Divide the horizontal distance into five equal intervals by finding four equally spaced positions along the horizontal distance between the end of the launcher and the impact point. Fill in the horizontal positions in the table.

The ball travels across each horizontal interval in equal time. The ball drops under constant acceleration during each interval. From the total distance it drops, figure out how far it will drop during each interval. Fill in the vertical drops in the table.

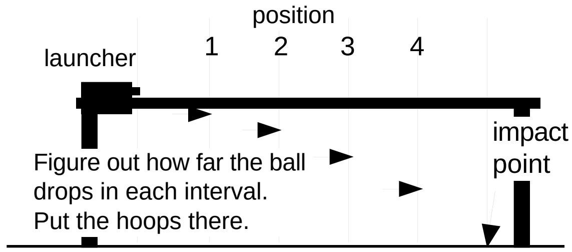

Figure 2: Trajectory of the ball

	horizontal distance	vertical drop
launcher	0 m	0 m
position 1	________	________
position 2	________	________
position 3	________	________
position 4	________	________
impact (data from above)	________	________

Measure the position for the first hoop. Place the hoop there, sticking it to the board using velcro. Fire the launcher. If the ball misses make any adjustments and recalculations as necessary.

After the first hoop is in place, continue with the second hoop and so on.

When all hoops are in the right place, sketch a scale drawing showing the hoop positions. Demonstrate to an instructor.

Calculate the horizontal launch velocity of the ball. $v_o =$ ____________________

Part 2: Conservation of Energy

What to Do

Predict how high the ball would go when it is launched vertically, straight up.

Before we go on. Make a guess and write it here: Guessed h_{max}= ....

How to get it right

You can use the principle of energy conservation to predict the maximum height of a ball launched straight up.

- Assume the initial kinetic energy of the launched ball is the same in the vertical position as it is in the horizontal position.

- As the ball climbs up, its kinetic energy is converted into gravitational potential energy.

- The ball will be at its maximum height when all of the ball's kinetic energy is converted into increased gravitational potential energy of the ball.

1. Write the formula for the initial kinetic energy of the ball: KE_0 = ...

2. Write the formula for the gravitational potential energy of the ball as a function of its height. Let the PE at the launch position =0.

   PE_g = ...

3. Equate KE_0 and PE_g. Solve for h_{max}:

4. Calculate the value of h_{max} by using the last formula you derived. Assume that the mass of the ball is 0.0164 kg and use v_o from part 1.

Predicted h_{max}=...............................

Now check it

Change the position of the launcher to an inclination of 90°. Launch the ball and measure the maximum height reached by the ball. One way to do this is to hold a meter stick behind the launcher and mark the maximuim height on the stick with tape. Repeat two more times and average the three measurements.

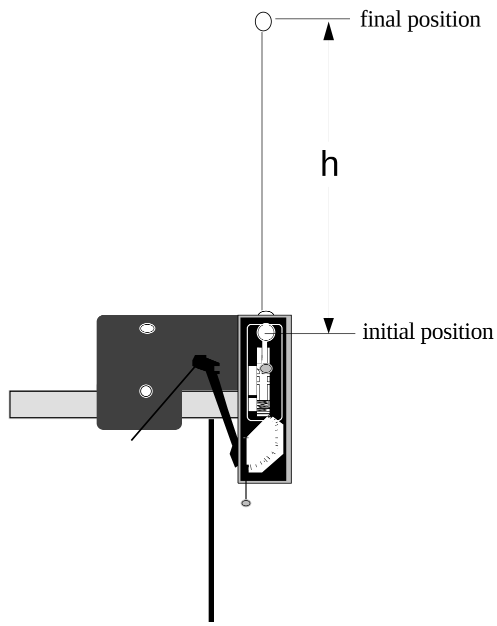

Figure 3: Vertical Launch

h_1=.................... h_2=...................... h_2=.................... h_{av}=......................

Reflect

Question	Answer (Circle one)
1. How good was your initial guess?	Good Bad Ugly
2. How well did the measured value compare with that which you predictedby calculation?	Good Bad Ugly
3. If the mass of the ball were increased, how would the maximum height it reached be affected?	Higher Same Lower

4. At its maximum height the added potential energy comes from the kinetic energy of the ball at launch. Where did this kinetic energy come from?

5. What is the ball's increase in gravitational potential energy in joules?..................J

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Physics 100 Lab: EXPLOSIONS AND COLLISIONS

Two carts are pushed apart from rest as a result of a sudden force acting between them: an explosion. Two carts collide and bounce. Two carts collide and stick together. How does momentum help us understand what happens? You will find the answer in this lab.

You have two carts:

1) The *dynamics cart* (cart D) has a magnetic bumper on one side and a Velcro™ sticker on the other. The Velcro™ side also has a spring-loaded plunger which can apply a sudden force after being compressed and released.
2) The *collision cart* (cart C) has Velcro™ stickers and magnetic bumpers on both sides, but no spring-loaded plunger.

There are two metal bars for loading the carts with different masses.
The track is furnished with a rubber bumper on one end and a c-clamp bumper on the other.

Activity 1: Two-cart explosions

You can measure the *relative* velocities of the two "exploding" carts without a computer. When one cart arrives at the end of the track before the other you hear two bumps. If the carts are released at the centre of the track and travel with the same velocity they arrive at the same time and you hear one bump. The time from explosion to bumper impact is the same for both carts and we will call it "one clunk": $\Delta t = 1 \text{ clunk}$. If one cart moves faster, you can adjust the starting position so the faster cart travels farther and they can be made to arrive at the same time. The velocities of the two carts are

$$v_1 = \frac{\Delta x_1}{\Delta t} \qquad\qquad v_2 = \frac{\Delta x_2}{\Delta t}$$

where, for each cart, $\Delta x = x_{stop} - x_{start}$: its distance of travel from explosion to bumper. Assume the velocities remain essentially constant. Thus the velocity of each cart is proportional to the distance it travels and has units of m/clunk.

The momentum for each cart is got by multiplying the velocity by the mass:

$$p_1 = m_1 v_1 = m_1 \frac{\Delta x_1}{\Delta t} \qquad\qquad p_2 = m_2 v_2 = m_2 \frac{\Delta x_2}{\Delta t}.$$

Each cart and each metal bar have a mass of 0.5 kg.

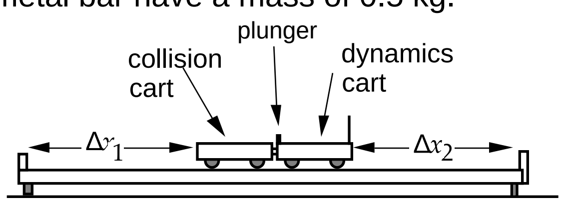

Fig: The position of the dynamics cart and the collision cart before the explosion and the distances each travels.

What to do

Fully compress and lock the spring plunger on the dynamics cart (cart D). To lock it, push it up slightly after compressing it so the slot in the rod catches on the metal edge at the top of the hole. Place cart D near the middle of the track. Place the collision cart (cart C) next to the plunger side of cart D so the spring will push against the second cart and the Velcro™ buttons stick to each other.

Release the spring by gently tapping on the release rod with the edge of the wooden block. (Using the block helps prevent accidentally giving the cart a horizontal push).

With the carts unloaded, find the explosion position which results in both carts reaching the track's end at the same time. Try to find the starting position to the nearest cm. You can mark the outside edge of one cart (its x_{start}) using the slider on the track. The x_{start} of the other cart is 34 cm away. Calculate the momentum of each cart after the explosion in units of "kg-m/clunk".

unloaded	m	x_{stop}	x_{start}	Δx	momentum
cart	(kg)	(m)	(m)	(m)	(kg·m/clunk)
cart C	0.5	0.015			
cart D	0.5	1.200			
				total p —>	

•Compare total momentum of the carts after the explosion to the total momentum before. ____

____

• Does the movement depend on which cart had the plunger in it?____________

Put one metal bar on the dynamics cart, find the starting position that gives one bump and calculate the momentum.

one cart	m	x_{stop}	x_{start}	Δx	momentum
loaded	(kg)	(m)	(m)	(m)	(kg·m/clunk)
cart C	0.5	0.015			
cart D	1.0	1.200			
				total p —>	

Prediction: If you were to put another 0.5 kg mass on the dynamics cart, predict where you would have to start for one bump. Fill in the x_{start} cells and then try it.

one cart really loaded	m	x_{stop}	x_{start} *predicted*	Δx *predicted*	momentum
	(kg)	(m)	(m)	(m)	(kg·m/clunk)
cart C	0.5	0.015			
cart D	1.5	1.200			
				total p $->$	

Activity 2: Elastic Collisions ("bump and run")

The collisions in this activity are elastic, because all the kinetic energy due to movement of the carts returns to the carts after the collision. The conversion of kinetic energy to potential energy during the collision is temporary.

What to do

Remove all the bricks from the carts. Turn the dynamics cart (cart D) around so that its magnetic bumper aligns with the magnetic bumper of the collision cart (cart C). Place cart D in the middle of the track and give cart C a gentle but firm shove towards it in the positive* direction and let them collide.

Elastic collision, both carts having equal masses	large negative*	small negative	zero	small positive	large positive
velocity of cart C before collision					
velocity of cart D before collision			X		
velocity of cart C after collision					
velocity of cart D after collision					

*Positive means towards the high end of the cm scale, negative towards the 0 cm end.

Put a mass bar in cart C. Repeat the collision and fill in the next table.

Elastic collision, hitter more massive than hittee	large negative	small negative	zero	small positive	large positive
velocity of cart C before collision					
velocity of cart D before collision			X		
velocity of cart C after collision					
velocity of cart D after collision					

Remove the mass bar from cart C and put it in cart D. Repeat the collision and fill in the table.

Elastic collision, hittee more massive than hitter	large negative	small negative	zero	small positive	large positive
velocity of cart C before collision					
velocity of cart D before collision			X		
velocity of cart C after collision					
velocity of cart D after collision					

• Explain the differences in the three collisions using momentum conservation.

____

____

____

____

Activity 3: Inelastic Collisions ("Hit and Stick")

If you turn the dynamics cart around so that the collision cart sticks to the Velcro™ then some of the kinetic energy is permanently lost to other forms of energy. Collisions where kinetic energy is lost are called inelastic collisions.

What to do

Repeat the collisions of the last section giving the collision cart about the same initial velocity each time. Record the relative velocities of the combined carts after the collision

Inelastic collisions	Velocity of combined carts after the collision.			
	zero	small	medium	large
$m_C < m_D$				
$m_C = m_D$				
$m_C > m_D$				

•Explain the differences in the three collisions using momentum conservation.___

____

____

____

If you have time, set up the ultrasonic motion detector to measure the velocities of the collision cart before and after the inelastic collisions. (21 cm above the track, 40 cm from its end.) Record the velocities of the collision cart immediately before and after the inelastic collision. Is momentum conserved during each collision? What happens to the kinetic energy?

	velocity of cart C before collision	velocity of carts after collision	Total momentum before collision	Total momentum after collision
$m_C < m_D$				
$m_C = m_D$				
$m_C > m_D$				

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Physics 100 Lab: Electrified Objects

When objects are rubbed they acquire a net electrical charge. All material consists of charged particles, but usually these charges are balanced so the material is said to be "uncharged" or neutral. Rubbing causes a small number of charges to be transferred from one material to another—the objects become "charged." While the exact mechanism of charge transfer is still not fully understood, the earliest qualitative electricity experiments using this effect occurred in the 18th century. Transfer of charged by rubbing is called called "triboelectricity." Giving something we don't understand a fancy name makes us feel better.

You can observe for yourself the behaviour of electric charges by rubbing plastic strips with paper or cloth. The ease of doing these experiments varies with atmospheric humidity because moisture adsorbed on surfaces allows charge to leak away. So if it's a warm, rainy day, be patient.

What to do

Two pieces of plastic hang from a ring stand: The clear strip is cellulose acetate and the white strip is Vinylite. Briskly rub each suspended piece of plastic with dry paper. Do not touch the rubbed surfaces. Rub another Vinylite strip with paper and bring it near each of the suspended strips.

• What happens?:____

Rub another strip of acetate with paper and bring it near the hanging strips.

• What happens?:____

• Have you found one, two or three kinds of charge? ____________________

• Assign names to each kind of charge you have found and use these names in the next exercise.

____

____

Rub some other objects. Hold them close to the charged plastic strips and discover what kind of charge they have. Try rubbing a plastic ruler, comb or balloon on your clothes. Try pulling apart two pieces of cellophane tape which were stuck together sticky-side-to-back-side. How are the surfaces charged after you pull them apart?

____

____

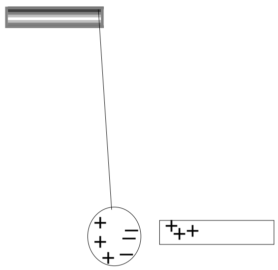
____

The original definition of positive charge was the charge acquired by a glass rod when rubbed by silk. Borrow the glass rod and silk and use it to identify the charges on the vinyl and acetate in terms of conventional terminology.

____

____

Attracting an uncharged metal ball



A small graphite coated ball hangs from an insulating thread. When you touch it you allow any excess charges on it to flow away through your body. This process is called “grounding.” Touch the ball momentarily to ensure that it is uncharged. Rub a piece of acetate and slowly bring it close to the metal ball.

What happens when the charged plastic strip comes near the ball?

What happens when the ball touches the charged strip? Why?

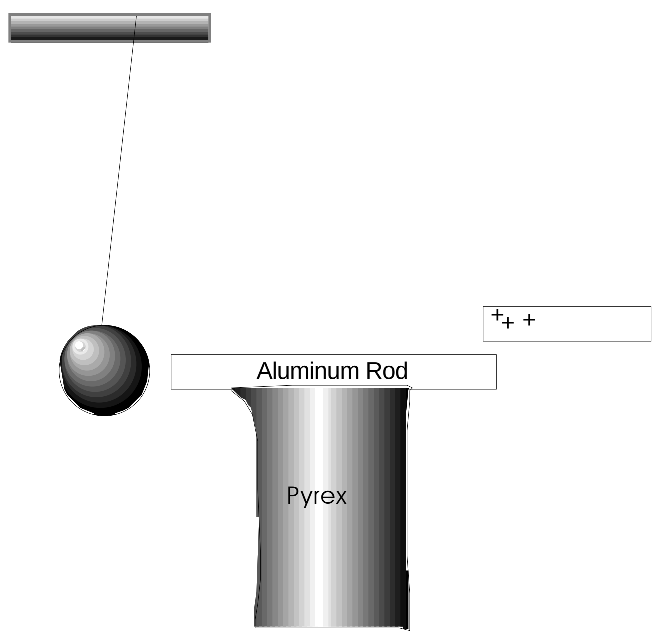
Touch the ball with your hand to discharge it and repeat the above experiment with Vinylite. Describe any differences or similarities.

Inducing charge

Place an aluminum rod on a beaker and put one end of the rod within 1 mm of the hanging metal ball. Touch the rod and ball to make sure they are discharged. Rub an acetate strip and bring it close to the aluminum rod. Try to get as close as possible but don’t touch the rod.

- Explain what happens to the ball by drawing the charges on the aluminum rod and on the ball. ——>

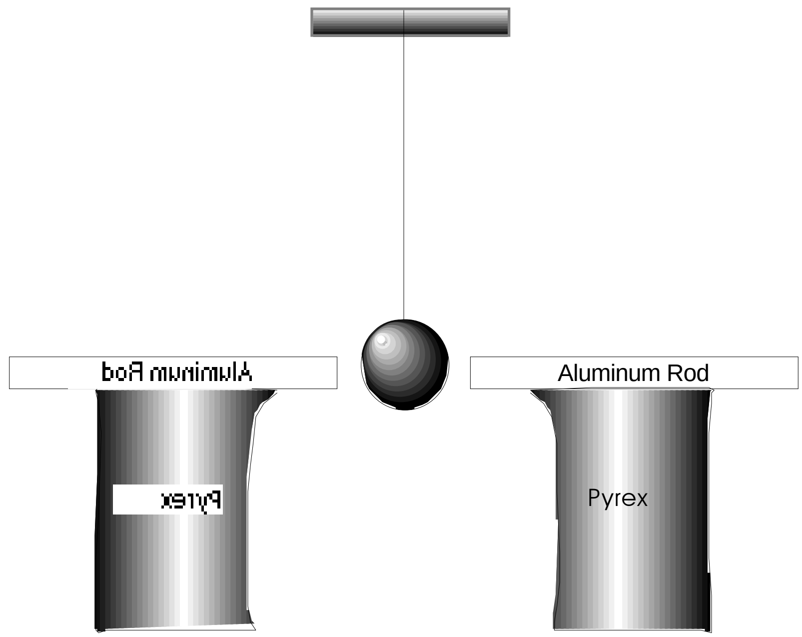
Replace the aluminum rod with a plastic rod and try to make the ball move.



Electric Ping Pong.

Hang the metal ball mid-way between two aluminum rods with a few mm clearance between the ball and each rod. Touch all the metal objects to discharge them. Rub an acetate strip, bring it close to the end of one of the metal rods as you did before. Hold it there for about 15 seconds and watch the metal ball.

Take the charged plastic strip away from the metal rod and keep watching the ball.



Can you explain what you see? Describe briefly what happened and try to explain it by drawing cartoons on the last page.

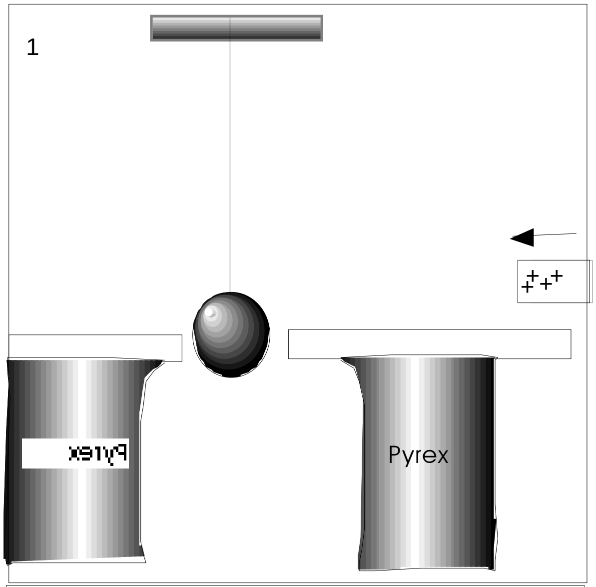
Party tricks*

Take some good tape, like electrical tape, into a very dark room. After your eyes have adapted to the dark, quickly pull a length of it off the roll while you and your friends are looking at it. You will see a bright flash caused by electrical sparks flashing as the surfaces get charged.

Also while in the dark room, crush a wintergreen lifesaver between the jaws of pliers. Bright flashes will amaze your friends. Do you still get bright flashes when you chomp on one with your teeth? What about other flavours? Try it!

* Did you ever learn party tricks in a Biology or Chemistry lab?

1



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Physics 100 Lab: REFLECTION AND REFRACTION

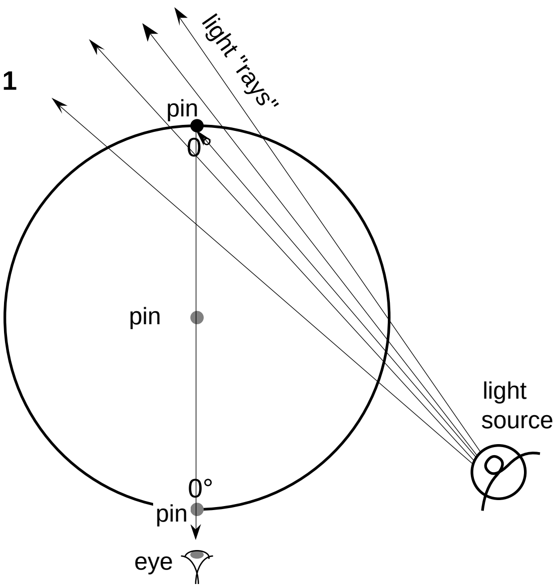
Many properties of light can be modelled by rays emerging from a light source, hitting an object and entering your eye. Optical devices can be understood by learning how lenses and mirrors change the paths of the rays in order to magnify, reduce or change the positions of images.

Straight line ray propagation

How can you show that light travels in a straight line? Put three pins in a straight line and sight down them. If the light reflected from the far pin passes the middle one and the near one before entering your eye then the pins will appear to be on top of each other.

Put three pins on the circular ray protractor supplied. Put one in the centre of the circle and two at the two 0° points. Are the pins in a straight line? When you sight down them with one eye can you move your head until they all appear on top of each other? Are you absolutely convinced that light travels in a straight line in this situation?

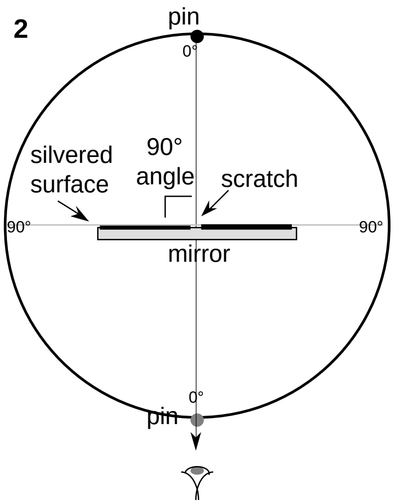
1



Reflection

When you look at an image of a pin in a mirror, you have no way of knowing where the light rays reaching your eye hit the mirror. If there is a scratch on the mirror and you move your head so that the image is lined up with the scratch then you know that the incident ray hits the mirror at the scratch.

2



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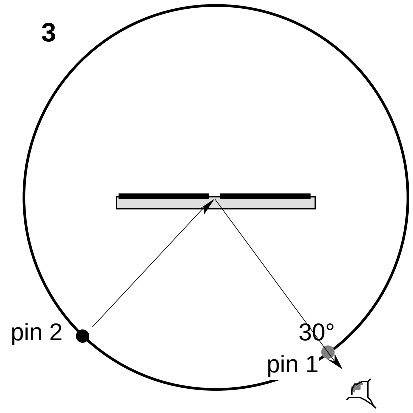


Remove the centre pin. Place the mirror with its scratch over the circle's centre point and its back on the 90°–90° line .

If you sight down the pin towards the scratch you should see

1. the near pin,
2. the image of near pin in the mirror,
3. the far pin over the top of the mirror and
4. the scratch on the back of the mirror.

All four should appear on top of each other. If not then the mirror is probably not placed exactly right. **Once this alignment is attained don't move the mirror while you do the next step.**

Remove pin 1 and place it at the 30° mark. Sight from pin 1 to the scratch on the mirror and place pin 2 so its image in the mirror appears in line with the scratch and with pin 1. Make sure pin 1, the image of pin 2 and the scratch all look like they are on top of each other.

Now a light ray from pin 2 strikes the mirror at the scratch and reflects back into your eye.

What is the angle of incidence? ___________________
What is the angle of reflection? ___________________

Reverse the procedure. Place pin 2 at some other angle (in front of the mirror) and find the position of pin 1 that aligns the pins and the scratch when you sight through pin 1 towards the scratch.

What is the angle of incidence? ___________________
What is the angle of reflection? ___________________

In both cases angles of incidence and reflection should agree within the accuracy of your pin-sticking.

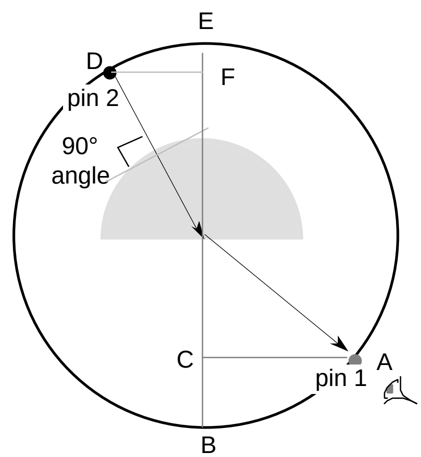
Have your partner stick a pin at a third location. Predict where you would have to stick the other pin so they appear aligned and then put the pin there and check. Sight from both pin 1 towards the scratch and from pin 2 towards the scratch, in other words, check the reversibility of the ray's path.

Did you succeed in predicting the correct position? Of course.
Is the ray's path reversible? ________________________________.

Refraction

There's a semicircular Lucite™ block which you can use to explore how light is refracted. Put the flat face of the Lucite™ block on the ray protractor centred on the 90°–90° line . The vertical line in the middle of the flat face should lie on top of the protractor's centre point. Stick pins in both 0° marks and sight along them through the plastic block. You should see both pins and the line on top of each other because the light ray from the pin passes through from air to plastic and from plastic to air at a 90° angle to the surfaces.

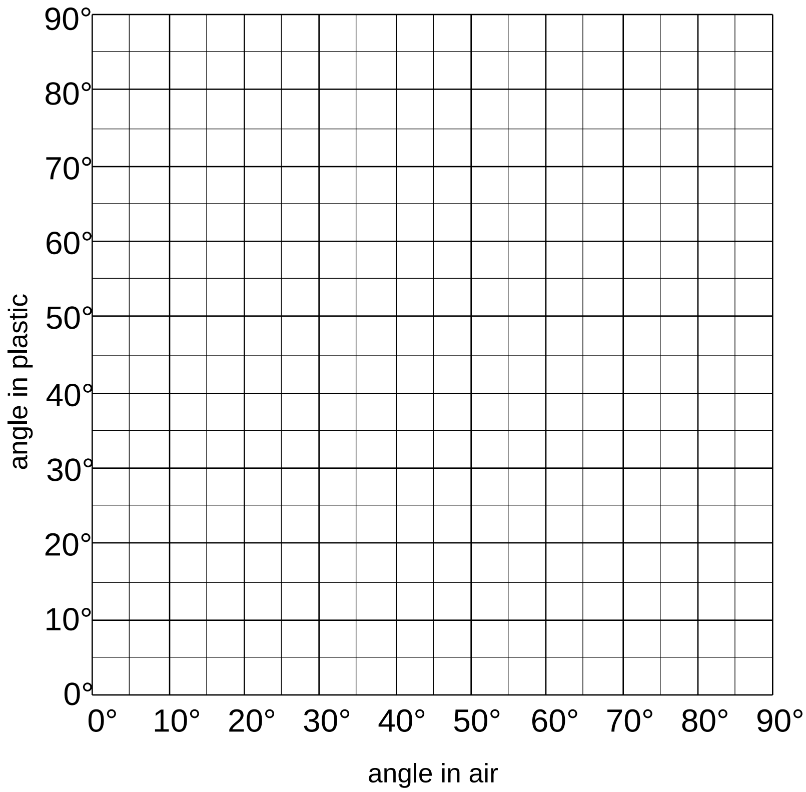
Move the near pin (pin 1) to the 10° point. Sighting along pin 1 to the line on the plastic and look *through the plastic block* find the position of pin 2 where both pins and the line appear on top of each other. Notice that the ray from pin 2 will always hit the curved side of the plastic block at right angles. The angle of the ray in air with respect to the normal to the surface is the position of pin 1 on the circle and the angle of the ray inside the plastic is given by the position of pin 2 on the circle. This angle would be the same if the plastic block were bigger than the protractor and the pin were inside the plastic.



The length of the semicords DF and AC can be read from the linear scale on the ray protractor. This length of the semicords in decimetres is equal to the sines of the angles. Make readings at angles shown in the table.

angle in air (pin 1)	angle in plastic (pin 2)	length of semicord AC (dm)	length of semicord DF (dm)
0°	0°	0	0
10°			
20°			
40°			
60°			
80°			

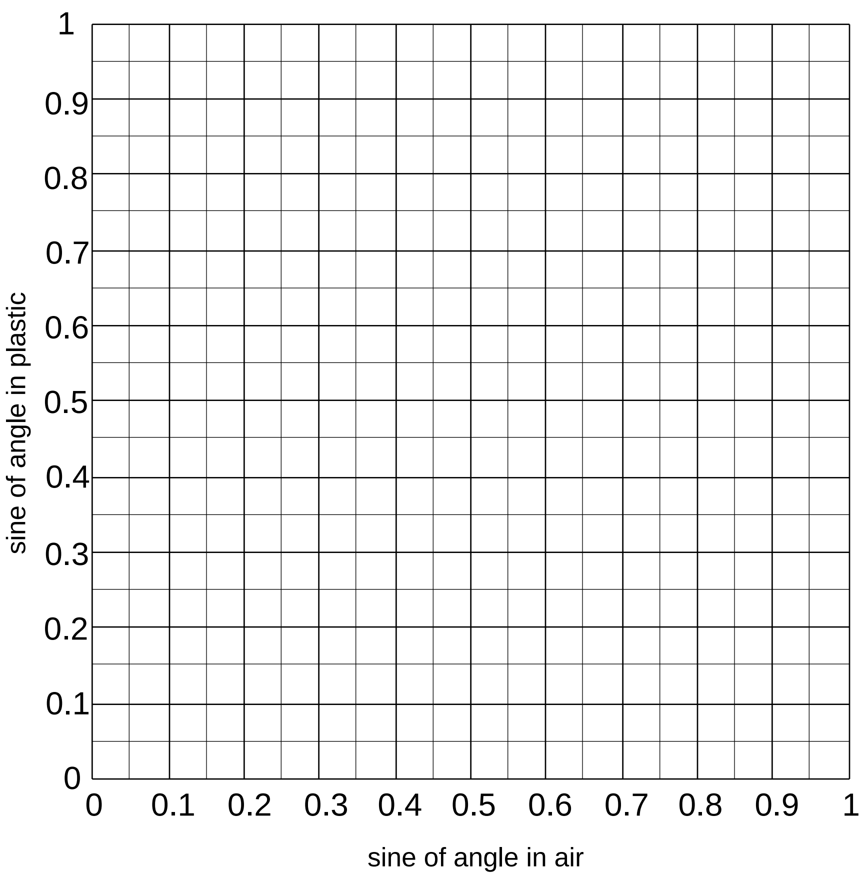
Plot the six angles in plastic vs. the six angles in air on the next page. Then plot the sines of the angles.



Estimate the index of refraction by calculating 1/slope of the graph at small angles.______________

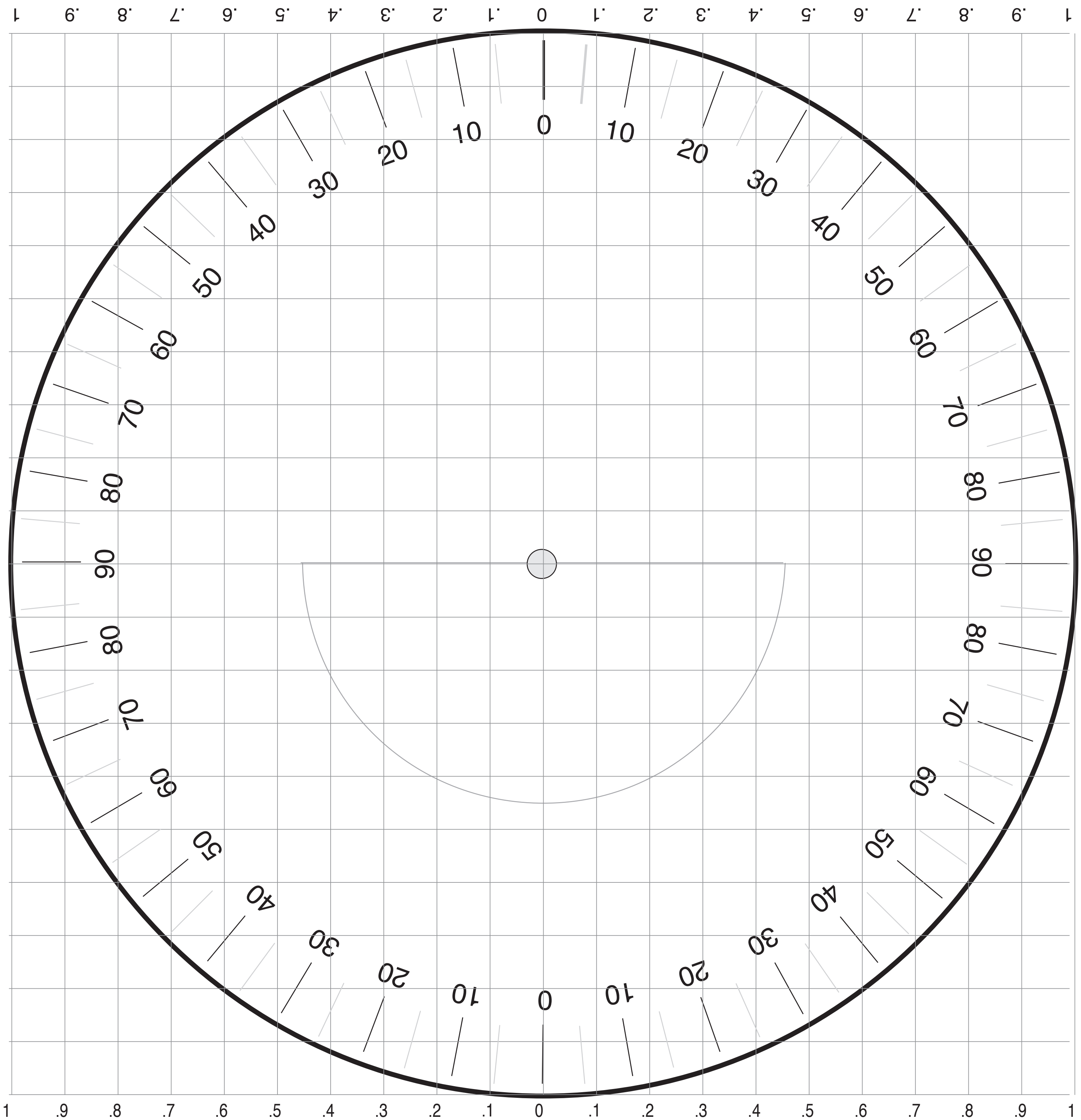
Estimate what incident angle (θ_c) in plastic would give a 90° angle in air._____

What would happen to the ray in air if the ray in plastic were incident at an angle greater than θ_c?___
____
____
____
____
____



Does this graph of the sines of the angles appear linear throughout the entire range of observation?_____

What index of refraction do you get from this graph? _



1 .9 .8 .7 .6 .5 .4 .3 .2 .1 0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1
0 10 20 30 40 50 60 70 80 90 80 70 60 50 40 30 20 10
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1 .9 .8 .7 .6 .5 .4 .3 .2 .1 0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1