5.8: One-Dimensional Motion

Name: ____

Date: ________________________

Partners:____

Equipment

• *LabPro* Interface • Motion detector • *Motion* software file	• Dynamics track • Dynamics cart • Lab jack

Introduction

A motion detector is a device that can track the position of an object as it moves. In many ways, a motion detector is similar to a bat. The motion detector, like a bat, emits brief "chirps" of very high frequency sound and then "listens" for the echo of this sound. By measuring the amount of time between emitting the chirps and hearing their reflection, the detector, like a bat, can determine the distance to the object that reflected the chirps. The bat then tries to eat the object, while the motion detector merely presents the data as a graph of the object's position vs. time.

In constructing a graph of position vs. time, the motion detector always serves as the origin of the coordinate system, and the direction the detector points is the positive direction. Using this position vs. time data, the *LoggerPro* software can calculate the velocity and acceleration of the moving object.

Note that the motion detector detects the closest object directly in front of it, whether this is the object of interest or not. Additionally, the detector will not correctly measure anything closer than about 15 cm, so objects closer than this distance result in erroneous measurements. Because of these two factors, motion detectors are very prone to extraneous readings. ***It is your responsibility to repeat any measurement until you are sure the detector has properly recorded the motion under investigation. Do not be tentative about repeating observations several times until no extraneous signals are present in your data.***

I. Constant Velocity

A. Position vs. Time Graphs

Place the cart about 15 cm in front of the motion detector. Give the cart a quick push away from the detector. The cart should roll with approximately constant velocity across the track. If necessary, clean the track and/or check the wheels of the cart to ensure a smooth motion. If the wheels of the cart do not spin freely, get a new cart!

Open the file *Motion.*

Collect position vs. time graphs for the following three motions:

- Rolling away from the detector
- Rolling away from the detector at a greater speed
- Rolling toward the detector

To collect data, press the **Collect** button and wait for the detector to begin "clicking", and then give the cart a quick push. If the data is clean, select **Experiment/Store Latest Run**. If the data is noisy, diagnose the problem and repeat the observation until the problem is solved.

Once you have recorded the three motions, prepare your graph for printing. In general, you will be graded on both the *quality* of your data and the *presentation* of your data. To properly present data in graphical form, you must always:

- add a descriptive title to your graph (right-click on the graph and select **Graph Options/Graph Options** tab),
- add you and your partners' names to the footer (**File/Printing Options**),
- make sure each axis is properly labeled with appropriate units,
- annotate your graph if it contains more than one data set (**Insert/Text Annotation**),

- and adjust the x- and y-axis ranges to best present your data (right-click on the graph and select **Graph Options/Axes Options** tab).

Once you've prepared your graph, print your graph and attach it to the end of this activity.

Question: Clearly explain how the direction of travel of an object can be determined from a position vs. time graph.

Question: Clearly explain how the speed of an object can be determined from a position vs. time graph.

B. Velocity vs. Time Graphs

To see a graph of the cart's velocity vs. time, select **Position** on the vertical axis and change the axis to **Velocity**. Adjust the scale to see all three motions (right-click on the graph and select **Graph Options/Axes Options** tab). Delete the text annotations.

Question: Can the direction of travel of the cart be determined from a velocity vs. time graph? Explain.

Question: Can the position of the cart be determined from a velocity vs. time graph? Explain.

Question: Can the *change in position* of the cart during a time interval be determined from a velocity vs. time graph? Explain.

C. Relating the Position and Velocity Graphs

Display both the position and velocity graphs for the rolling away motion. (Select **Velocity** on the vertical axis and select **More…** . Then check both the Position and Velocity boxes for the appropriate run.)

Determine the value of the slope of the position vs. time graph and the value of the mean velocity.

- To determine the slope, click and drag to highlight a large, straight portion of the position vs. time graph, and then select **Analyze/Linear Fit**.
- To determine the uncertainty in the slope, right-click in the Linear Fit box and select **Linear Fit Options**.
- To determine the mean velocity, highlight the *exact same portion* of the velocity vs. time graph, and then select **Analyze/Statistics**.
- The standard deviation can be used as the uncertainty in the mean velocity.

Complete the table below. Remember, all data have units and associated uncertainties. In most cases, we will use the standard deviation as a measure of the uncertainty in the mean value of a set of data.

Motion	**Slope of x vs. t (m/s)**	**Mean Velocity (m/s)**
Rolling away	±	±
Rolling away at a greater speed	±	±
Rolling toward	±	±

Question: Are the two quantities measured above consistent, within measured uncertainties, for each motion analyzed?

E. Relating the Position and Velocity Graphs, Again

For each of the three motions, determine the area under a portion of the velocity graph and the corresponding change in the position of the object. Again, it is easier to do this one data set at a time.

- To determine area under the velocity graph, click and drag to highlight a large, horizontal portion of the velocity vs. time graph, and then select **Analyze/Integral**.
- To determine the change in position over exactly the same interval, select **Analyze/Examine**. A vertical cursor will appear that allows you to determine the position at the two ends of the region highlighted above.

The software does not automatically calculate an uncertainty for these measurements. However, this does not mean that the data is exact. Estimate and record an uncertainty for each measurement below.

Motion	Change in Position (m)	Area under v vs. t (m)
Rolling away	±	±
Rolling away at a greater speed	±	±
Rolling toward	±	±

Question: Describe and defend your method for estimating the uncertainties in your data.

Question: Are the two quantities measured above consistent, within estimated uncertainties, for each motion analyzed?

II. Varying Velocity

Erase your old data (**Data/Clear All Data**), and display only a position graph.

By elevating one end of the track (use a lab jack at its lowest setting) the cart can be made to move with a varying velocity.

Collect position vs. time graphs for the following three motions:

- Speeding up moving away from the detector
- Speeding up moving toward the detector
- Slowing down moving toward the detector

Of course, you will have to move either the lab jack or the motion detector to collect these three distinct motions.

As always, if the data is noisy diagnose the problem and repeat the observation until the data is clean. Once the data is clean select **Experiment/Store Latest Run**.

Once you have recorded the three motions, properly prepare your graph for printing, and then print and attach your graph.

Question: Clearly explain how to distinguish between an object that is speeding up, an object that is slowing down, and an object that is moving at constant speed based *only* on a position vs. time graph.

Display the velocity graph.

Question: Clearly explain how to distinguish between an object that is speeding up, an object that is slowing down, or an object that is moving at constant speed based *only* on a velocity vs. time graph.

Display the acceleration graph.

Question: Is it possible to distinguish between an object that is speeding up and an object that is slowing down based *only* on an acceleration vs. time graph? Explain.

Question: Does the algebraic sign of the acceleration have any relationship to whether the object is speeding up or slowing down? If not, what information does the sign of the acceleration convey?

Question: Is it possible for an object to speed up with a negative acceleration? If so, describe how this could be accomplished with the given lab equipment.

Question: Is it possible for an object to slow down with a positive acceleration? If so, describe how this could be accomplished with the given lab equipment.

For each of the three motions, determine the concavity of the position vs. time graph, the slope of the velocity vs. time graph, and the value of the mean acceleration.

Motion	Slope of v vs. t (m/s^2)	Mean Acceleration (m/s^2)
Speeding up away	±	±

Speeding up toward	±	±
Slowing down toward	±	±

Question: Are the two quantities measured above consistent, within measured uncertainties, for each motion analyzed?

III. Round-Trip Journey

Display a graph of position, velocity, and acceleration vs. time.

With the motion detector at the bottom of the incline, give the cart a quick push up the incline so that it travels almost to the top of the track before rolling back down. Of course, catch the cart before it collides with the motion detector. Once you have cleanly recorded this motion, prepare and print your graph and attach it to the end of this activity.

Label your print-out with the following three vertical lines:

- Draw a vertical line (through all three graphs) at the time the cart first leaves your hand on the way up the incline. Label the line "*Release*".
- Draw a vertical line at the time the cart comes to rest (momentarily) at the top of the track. Label the line "*Apex*".
- Draw a vertical line at the time the cart first strikes your hand on the way down the incline. Label the line "*Catch*".

Question: Clearly explain your reasoning for drawing each line where you did.

for line 1:

for line 2:

for line 3:

Question: Clearly explain why the acceleration is negative for both the motion up the incline and the motion back down the incline.

Question: Clearly explain why the accelerations immediately before *Release* and immediately after *Catch* are large positive values.

Question: Clearly explain why the acceleration is not zero at *Apex*, even though the velocity is zero at this point.

Imagine the motion repeated with the motion detector at the top of the incline.

Question: Clearly explain how this change in coordinate system will affect each of the three graphs.