Acceleration and Uniform Motion

Name: ______________________
Partner: ____________________
Partner: ____________________

Introduction:

Recall the previous lab

During Lab 1, you were introduced to computer aided data acquisition. You used a device called a Motion Detector that measured the time delays of reflected ultrasonic signals, which the computer used to calculate displacements. Very quickly, the computer graphed the displacement-time data. The shape of the graph immediately gave you information about the nature of the motion. During those activities, we looked at constant speed motion. The displacement-time graph was a straight line with a positive, negative, or zero slope. The velocity was correspondingly either positive, negative, or zero with approximately zero slope. Do you remember what a negative velocity meant?

The Motion Detector establishes a coordinate axis

The displacement measured by the Motion Detector was always a positive number. Walking away from the Motion Detector resulted in an increase in the displacement. This is the positive direction. Similarly, walking toward the Motion Detector (that is, walking in the negative direction) resulted in a decrease in the measured displacement, though the position was never negative because you were always on the positive side of the Motion Detector. Remember, \( \Delta x = x_f - x_i \).

Any vector with a direction pointing away from the Motion Detector will result in a positive number, and any vector with a direction pointing toward the Motion Detector will result in a negative number. For example, when you walk toward the
Motion Detector, your velocity (a vector) is toward the Motion Detector and will be a negative number. On the other hand if you walk away from the Motion Detector, your velocity will be pointing away from the Motion Detector and hence will be a positive number.

Materials:

Metal angle

PC with LabQuest interface for measuring instruments

Motion Sensor (also known as a "sonic ranger"): to detect the motion of a cart rolling on track

PASCO cart on aluminum tracks

Activity:

1. Average acceleration

Open Logger Pro 3.8.3. Set up the readout program as in Lab 1 with two graphs, position versus time and velocity versus time. Set the collection time to 5 sec if it is not already set to 5 sec. Collect data and ensure that the sonic ranger detects only the cart all along the track and not part of you or another object along the track.

Start moving the cart gently and smoothly back and forth along the track driving it with your fingers, keeping parts of your body that might be picked up the motion detector out of the way. Cover the range of about one meter in this back and forth motion. Don’t get too close to the motion detector since it has some dead space right in front of it (allow at least 15 cm separation). Collect the data. You should make 2 full cycles in the back and forth motion during the data collection period. You should see a wave-like graph on your screen. Try to make it smooth without any sudden steps or spikes in the entire time range. Once you are happy with the recorded result, Autoscale the graphs then use PRINT to copy your graph to the printer.

Indicate these Points on your graph:
A: middle point between farthest and closest distance from motion detector (cart moving away from motion detector)

B: next time moment when the cart came back to point A

C: between A and B when the cart was furthest from motion detector

Now analyze the $v(t)$ vs. $t$ graph in a similar way to that we used to analyze $x(t)$ vs. $t$ in the last laboratory. Using the “$v=?”” cursor applied to the graph of velocity calculate average accelerations in the time intervals AC and CB.

$$a_{AC} = \frac{\Delta v_{AC}}{\Delta t_{AC}} = \frac{(v_C - v_A)}{(t_C - t_A)}$$

<table>
<thead>
<tr>
<th>Time interval Average quantity</th>
<th>A-C</th>
<th>C-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Q1. Did the sign of average velocity change from AC to CB? Why?**

**Does the sign of velocity indicate the direction of motion?**

**Did the sign of the average acceleration change from AC to CB?**

**Does the sign of acceleration indicate the direction of motion?**
2. **Instantaneous acceleration**

To move on to the concept of instantaneous acceleration, activate the “tangent” cursor on the graph of velocity. Go to the point of maximal velocity and record the slope of the line tangent to the velocity graph. That will give you the instantaneous acceleration at that instant in time:

$$a_{(v_{\text{max}})} =$$

Now go to the point where the velocity is zero (in between the maximum and minimum velocity) and read out the instantaneous acceleration:

$$a_{(v=0)} =$$

Finally go to the point where the velocity is the most negative:

$$a_{(v_{\text{neg}})} =$$

**Q2. When the cart is moving fast, does it mean that the acceleration is large?**

When object momentarily stops (zero velocity), is the acceleration zero?

3. **Graph of instantaneous acceleration \(a(t)\)**

Add the graph of acceleration versus time to your screen (this will be the third graph on your screen). To do this: Go to ‘Insert’ on Menu. Click on Graph which will add the graph. Go to Page and click ‘Autoarrange’ (or Ctrl r). Click on labels of graphs to switch between position, velocity and acceleration as needed. The best would be top to bottom Position, Velocity and Acceleration. PRINT the graphs.

**Q3. Compare, using “tangent”, the slopes of the velocity curve with the “\(a=\)”s on the acceleration curve at the same times. Are they the same? Why?**
We could continue our procedures and analyze this graph the same way we did previously, that is, use the “tangent” cursor to find the derivative of acceleration with respect to time, \( \frac{da}{dt} \), at different moments in time. It turns out that such activity is not very useful from the dynamical point of view, and we have no need to go beyond the second derivative of position over time (\( a = \frac{dv}{dt} = \frac{d(dx/dt)}{dt} = \frac{d^2x}{dt^2} \)). While kinematics deals with description how objects move, dynamics deals with explanation why they move. We will explore these relationships during an upcoming laboratory.

**Different types of motion**

We’re going to study different types of the motion you may already be familiar with. We are interested in measuring kinematic quantities to see whether they remain constant or not. You will do some familiar experiment and fill out the following table. Some table spaces are nonsense. Please find them and mention why they are nonsensical. In addition, *please explain what graph you used to determine each value*. 

To investigate motion use the three graphs; position vs. time, velocity vs. time and acceleration vs. time that you have set up. Make sure that the motion detector detects the cart all along the track. *PRINT* the three graphs.

Do not use scientific notation to write down the value; remember, the motion detectors are accurate to perhaps 3 to 5 mm.
4. **Constant position**

1 To measure quantities within selected time ranges, left-click on the associated graph with the pointer positioned at the lowest time you want to include in the average (the pointer should be within the rectangular area defined by the graph axes), hold the mouse button down and stretch the selection range to the largest time to be included in the average. Vertical bars superimposed on the graph, connected by horizontal dashed lines, will indicate the selected range. If you are not happy with the selection just repeat the procedure. To average the position measurements within the selected range click on the “STAT” button. The average value (called also the “mean”) will be displayed in a small box superimposed on the graph.

2 To “fit” means to adjust values of free parameters, so the formula gives the best match to the collected data. The program can do the fit for you! Select the time range on the position graph to be used in the fit (the same way you used to select it for averaging). Use the same interval as used to calculate the average values listed above. Go to “Analyze” menu and select your desired fit. The fitted line will be superimposed on your data extending also beyond the selected time range.
An object at rest doesn’t move. Yet all kinematical variables: position, velocity and acceleration can still be measured. Thus, being at rest is just a very special type of motion.

A measurement process always carries some inaccuracies called measurement errors. They may show up as oscillations of the measured value around the true value, fluctuating with time.

5. **Constant velocity**

Now try to realize motion in which position changes but velocity remains constant. Give the cart a strong push and let it go. Be sure someone is catching the cart. PRINT the graphs. Identify and mark parts of your graph that correspond to this type of motion. Indicate the range of values of each kinematical variable on the vertical axis.

**Q5. How does the position depend on time in this case?**

**What can you say about the acceleration?**

**Q6. What is the function you need to use for fitting?** Does the fitted line match your data well within the selected range? Explain which parameters describe quantities we are looking for.

**Q7. Is it close to the value you obtained by averaging the velocity data?** What criteria did you use to decide whether $v_{fit}$ is close to $v_{avg}$?
6. **Constant acceleration**

Finally we will investigate motion in which position and velocity vary but acceleration remains constant.

To produce constant acceleration, we will take advantage of gravity, which produces a constant force on an object. According to Newton’s Second Law, which we will study later, acceleration is proportional to the force, so if the force is constant, the acceleration remains constant.

Collect the data while you allow the cart to roll down freely. **Please catch the cart. Be sure the cart does not roll off the table.** PRINT the graphs. Identify and mark parts on your graph that correspond to this type of motion. Indicate the range of values of each kinematical variable in the vertical axis.

**Q9. How does the velocity depend on time in this case?**

**Q10. Any ideas what kind of function would describe the dependence of position on time and velocity on time?**
Q11. Is the fitted value of the acceleration close to the average value determined above? How are you deciding what is ‘close’?

Using your fitted line find the initial velocity.

$v_0 =$

Let’s learn about some other tools available to us in LoggerPro. Looking at your v-t graph, find a region where there are no obvious glitches in your data, i.e. no sudden or sharp spikes. Select and shade a region by clicking and dragging the cursor across the graph. This will highlight a portion of your v-t graph. Under Analyze, choose the Integral tool. A box displaying the area under the shaded v-t curve should appear in your graph. You can click and drag this box to a convenient location out of your way.

Q13. What is the physical meaning of the value of this integral?

Q14. Using the data on your screen, how can you verify that the integral is correct?

Q15. Please show your calculations below.

Q16. You need not do this, but what would an integral of some region under your a-t graph give? How could you verify this?
7. **Different initial conditions for motion with constant acceleration (optional if time permits)**

Without changing the tilted track inclination used for Activity 6, place the cart near the lower end of the track. Give the cart a push upwards on the track, until it stops without getting too close to the sonic ranger, and then rolls back down. You may need to practice until you manage to obtain the desired trajectory. PRINT the graphs and mark them as before after you have finished the rest of the fitting described on this page. Repeat the averaging and fit procedures as in Activity 5.

Find the average acceleration from the \( a(t) \) vs. \( t \) graph: (keep the statistics fitting box on the screen).

\[ a = \]

Linear fit to the \( v(t) \) vs. \( t \) graph: (keep the fitting box on the screen)

\[ a_{fit} = \]

\[ v_0 = \]

Quadratic fit to the \( x(t) \) vs. \( t \) graph: (keep the fitting box on the screen)

\[ a_{fit} = \]

\[ v_0 = \]

*Q17. Do the acceleration and initial velocity values determined in different ways agree?*

*Is the initial velocity close to the value in Activity 6? Please explain how you determine the meaning of ‘close’.*

*Is the value of acceleration close to the value in Activity 6?*
Pre-Lab Questions

Print Your Name

Read the Introduction to this handout, and answer the following questions before you come to General Physics Lab. Write your answers directly on this page. When you enter the lab, tear off this page and hand it in.

1. You stand in front of the Motion Detector and let Logger Pro record your displacement. Is the displacement Logger Pro assigns you positive or negative?

2. If you walk toward the Motion Detector, does the displacement that Logger Pro records get larger or smaller?

3. Suppose you walk towards the Motion Detector and let Logger Pro record your velocity. Is the velocity that Logger Pro calculates positive or negative?

4. The same as the previous question, but you are walking away from the Motion Detector instead of towards it.

5. Suppose the Motion Detector is mounted on the ceiling and pointed so that it can record the displacement of objects beneath it. In the resulting Logger Pro graphs (with displacement on the vertical axis and time on the horizontal axis), does the positive direction represent up toward the sky or down toward the center of the earth?

6. Write the kinematic equation that gives displacement as a function of time for an object that is experiencing motion with constant acceleration. (Hint See page 9.)

7. Suppose you used Logger Pro and the Motion Detector to graph Displacement versus Time for an object thrown vertically, and, further, you had Logger Pro do a fit to the graph to determine the equation that describes Displacement as a function of Time. The general form of the equation that Logger Pro gets from doing the fit to the graph is \( x = C + Bt + At^2 \), and Logger Pro tells you the values of the constants \( A \), \( B \), and \( C \). Suppose Logger Pro says that \( C = 1.2 \), \( B = 0.3 \), and \( A = 4.82 \). Use this information along with your answer to pre-lab question 6 to determine the acceleration of gravity, \( g \), in \( \text{m/s}^2 \). (The answer to this question is \( \text{not} \ 9.8 \ \text{m/s}^2 \).)

Which way was the object thrown? Up or down? How can you tell?
8. In the blank graph immediately below, take the origin of the coordinate system to lie on the floor of the lab, take *up* to be the positive direction, and draw the shape of a Displacement versus Time graph for a ball that is thrown straight upward but then falls back to the ground. Label the axes. (This is not discussed in the *Introduction* to this handout. Refer to your general physics text, if necessary.)

![Graph for Pre-Lab Question 8](image)

**Graph for Pre-Lab Question 8**

9. The same as the previous question, but this time take the origin of the coordinate system to be on the ceiling in the lab, and take *down* to be the positive direction.

![Graph for Pre-Lab Question 9](image)

**Graph for Pre-Lab Question 9**