Pre-Lab Exercises

Full Name:

Lab Section:

Hand this in at the beginning of the lab period. The grade for these exercises will be included in your lab grade this week. Feel free to look for the answers to questions 1 and 2 online.

1. What is the formula that describes how the acceleration of an object down an inclined plane depends on the angle the incline is elevated (with respect to the horizontal)? Note, after you learn about forces and inclined planes, you should try deriving this yourself.

2. What are the maximum and minimum values of the square of the Pearson product correlation coefficient (R-squared)? What do these values mean in terms of how the independent and dependent data sets are related?

3. In the position formula \( x(t) = At^2 + Bt + C \), what is the value of the acceleration in terms of \( A \)?

4. In the velocity formula \( v(t) = At + B \), what is the value of the acceleration in terms of \( A \)?
Acceleration Due to Gravity on an Inclined Plane

Full Name:

Lab Partners’ Names:

Lab Section:

Introduction:
The purpose of this experiment is to have you determine the acceleration due to gravity accurately using an inclined plane, the motion sensor, and a dynamics cart. Throughout this experiment, you will also be gaining more practice with Microsoft Excel. Feel free to ask your instructor if you have any questions. Again, be sure to complete all of the bold-faced items, as they will form the majority of your grade for this experiment.

Equipment:
- Science Workshop interface
- Dynamics Track and Cart
- Motion Sensor
- Bubble Level
- Wooden Blocks
- Wooden Wedge
- Masses
- Balance (500 grams+)

Procedure:
1. Setting up the equipment:
   1.1 Make sure the Science Workshop interface is connected to the computer. Turn on the interface first and then turn on the computer. This may already be done for you.
   1.2 Open DataStudio (icon should be on the desktop).
      1.2.1 Select “create experiment”
      1.2.2 Follow the instructions. Click any channel to add a sensor and choose Motion sensor and double click it. Look at the icon and determine which lead (yellow, black) goes to which of the 4 channels.
      1.2.3 Under the Measurement tab, set the Sample Rate to 50. This is the frequency with which the sensor will take displacement readings.
      1.2.4 Under the “Measurement” tab, make sure that Position and Velocity are selected.
      1.2.5 Close the Experiment Set Up window
1.2.6 Under the display window on the lower left, select “graph”, ensuring that the data source is position.

2. Measuring the displacement:
   2.1 Connect the motion sensor to the end of the track without the bumper.
   2.2 Adjust the leveling screw on the bottom of the track, which is located on the bottom of the bumper, until you have leveled the track. The bubble level will be very helpful here.
   2.3 Raise the end of the track with the motion sensor so that you create an angle more than 10 degrees and calculate this angle. Use 16 wooden blocks and the wooden wedge placed under the detector to do this. **Check with your TA to ensure you are calculating the angle properly.**
   2.4 Hold the cart, flat side facing the sensor, 50 cm away from the sensor. Press the button in DataStudio. **Have your partner hold the track steady. Otherwise the cart and the track WILL fall when the cart hits the bumper.** Give the cart a push up the track and let it stop and roll back down.
Ensure that there are four bounces on each graph.

2.4.1 Your position - time graph should resemble one from the bouncing ball experiment.

2.4.2 If the data plot is not smooth, check the alignment of the motion sensor and retake data. Changing the switch on top of the motion sensor to “wide cone” may also help. Also check to make sure the dial on the side of the detector is set so that the sensor is aligned with the track.

2.4.3 Re-scale the graph as necessary to provide a good picture of the motion. You do this by selecting the interesting data points and clicking the resize button (źródlo) on the left side of the tool bar immediately above the graph.

*Note: If your cart gets too close to the motion sensor you will see a flattened out portion at the bottom of the “bounce.”*

2.5 Record the sine of the angle of the track the measured acceleration for the first three peaks on your first run in the table on the next page. (See section 3 on calculating the acceleration of the cart down the track.)

2.6 Once you have a good set of data, set the track to a different angle and repeat the data collection. You must acquire the acceleration data for the first bounce for four more different angles. The number of blocks is specified in the table. For the larger angles, you will need to use the wooden wedge between the wooden blocks and the detector to ensure that the detector is at the same angle as the track. **Make certain your cart rolls smoothly for small angles – if not, ask your TA to substitute a different cart.**

2.7 Measure the mass of the cart, as well as the mass of the two masses provided. Repeat the data collection with one mass added and one run with two masses added. **Use only two blocks as the height of the track for this experiment.** Determine the acceleration for these carts the same way you have previously.

Below is a data table you can use to keep track of the data you will collect during this experiment:

<table>
<thead>
<tr>
<th>Run #</th>
<th># of Black Masses</th>
<th>Total Mass (kg)</th>
<th># of Blocks</th>
<th>Height H₂ (cm)</th>
<th>Height H₁ (cm)</th>
<th>Ramp Length L (cm)</th>
<th>Sine θ</th>
<th>Measured Acc (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bounce 1</td>
<td>0</td>
<td>16</td>
<td></td>
<td>H₂</td>
<td>H₁</td>
<td>L</td>
<td>(H₂ - H₁) / L</td>
<td></td>
</tr>
<tr>
<td>1 Bounce 2</td>
<td>0</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Bounce 3</td>
<td>0</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>20</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
3. Data manipulation:
   3.1 Open a new graph for your data, this time selecting velocity vs time.
   3.2 For the purposes of this lab, it is faster to perform a linear fit on your data in DataStudio than in Excel, as you did in lab 1. Using the mouse highlight the data you would like to "fit".
   3.3 Select the Fit button from the main toolbar immediately above the graph.
   3.4 A pull down menu will appear with the fitting options.
   3.5 Select the linear fit option.
   3.6 DataStudio will determine the equation that best fits the data you have taken. DataStudio will then supply the coefficients for the terms in the equation of motion. One will come before the linear term (A), and the other is a constant (B). Be sure to print one of the graphs you have performed a fit on.
      Record the measured acceleration from this equation in the table. Repeat for the rest of your data.
   3.7 In Excel, plot the measured acceleration (y-axis) vs the sine of the angle (x-axis) for the runs without any mass added to the cart (Runs 1-5).
   3.8 Select the points on this graph and generate a linear fit to the data, include the R-squared value and fit equations on the graph (Highlight the data and click on “chart” in the toolbar. Choose “Add Trendline.” Add the equation and the R-squared values by selecting the last two check-boxes under the “options” tab). Print the graph with the trendline, the “fitted equation” and R-squared values on them. Note: There should be five points on this graph.
   3.9 Plot the acceleration (y-axis) versus the mass of the cart (Runs 5, 6, 7). Print this graph as well. Note: There should be three points on this graph.
   3.10 For the first trial, plot the acceleration vs the number of the bounce the cart is On (Run 1 only). Print this graph. Note: there should be three points on this graph.
   3.11 Include a copy of your data like the sample table given on the previous page.

You should be handing in a neat, labeled and titled graph of one data run, as well as three different plots generated by Excel. Make sure trendlines appear:
   1) acceleration vs. sine of angle (Runs 1-5)
   2) acceleration vs. mass (Runs 5, 6, 7)
   3) acceleration vs. number of bounce (Run 1 only)

Questions:
1. How did you calculate the angle of the track? Describe explicitly what measurements were taken and show your calculations.
2. What is the significance of the slope of this trendline in section 3.8? Hint: Review your prelab.
3. What is the percent error between the slope of your trendline and the expected value?
4. Using your trendline equation for the measured acceleration versus sin\theta, what would be the acceleration if the cart were placed on a) a horizontal track? b) a vertical track?
5. From your data, does the mass of the cart significantly affect the measured acceleration? Give a quantitative answer by consider the following:
The trendline in your plot of acceleration vs. mass, has a relatively small positive slope. From your three data points, calculate and then draw on this plot, the average acceleration as a horizontal line (zero slope). From each data point, determine an uncertainty bar $\Delta A$ that covers the distance from each data point to the average acceleration line. Determine which of these is the largest. It is with this uncertainty $\Delta A_{\text{max}}$ that the acceleration is a constant for all three data points and hence the acceleration is not dependent on mass. Fill in the following table to determine the uncertainty $\Delta A_{\text{max}}$ and draw it on each of the data points.

| Run | Mass (kg) | Acc $(\text{m/s}^2)$ | $\Delta a = |\bar{a} - a_i|$ |
|-----|-----------|---------------------|-------------------------------|
| 5   |           |                     |                               |
| 6   |           |                     |                               |
| 7   |           |                     |                               |

$\bar{a} = \frac{\sum a_i}{n}$

$\Delta a_{\text{max}} = \max |\bar{a} - a_i|$

$\frac{\Delta a_{\text{max}}}{\bar{a}}(\%) = \frac{\max |\bar{a} - a_i|}{\bar{a}}(\%)$

If the fractional uncertainty $(\Delta a/\bar{a})$ for each data point is greater than ___%, then the acceleration can be considered independent of the mass of the cart.

6. How did the acceleration change with the number of bounces? Why or why not?
7. Look at the acceleration during the time when the cart is in contact with the bumper. Is this acceleration in the $+$ or $-$ $x$ direction? Is the magnitude of this acceleration larger or smaller than during the rest of the data run, that is, when the cart is accelerating down the track or decelerating up the track?