Incline

Goals: Use a digital measuring device to acquire data. Operate a computer interface for an experiment. Analyze numeric data from a table and a graph.

APPARATUS

Galileo Galilei (1564-1642) used an inclined plane with minimal friction to observe motion due to gravity. The track in this experiment is more technically sophisticated, but the idea is the same as it was 400 years ago. The height of the incline can be adjusted to change the angle of the slope. A cart moves up and down the incline, and an acoustic motion detector senses the position of the cart at a sequence of times.

The data will be recorded with Logger Pro software. When the software is open there is a window on the left side of the screen with columns labeled time, position, and velocity. On the right side there are two graphs, one to show position versus time, and the other to show velocity versus time.

THEORY

An object sliding down an inclined plane without friction is subject to a constant acceleration (a). The acceleration is due to the gravitational acceleration (g), but the acceleration on the slide is reduced because the track is at an angle. The full gravitational acceleration would only occur if the object fell straight down and the object would then be in free fall. The gravitational acceleration near the earth's surface is $g = 9.8\ \text{m/s}^2$.

The reduced acceleration due to angle of the track can be expressed as

$$a = g\sin\theta \qquad \textbf{(EQ 1)}$$

where θ is the angle of the track compared to a horizontal surface. The sine of the angle can be found from two heights, h_1 at the higher point and h_2 at the lower point, and the distance L between them along the slope.

$$\sin\theta = \frac{h_1 - h_2}{L} \qquad \textbf{(EQ 2)}$$

So, for our track the actual acceleration for a cart should be

$$a = g\left(\frac{h_1 - h_2}{L}\right) \quad \textbf{(EQ 3)}$$

The acceleration (a) of an object is defined as the rate of change of the object's velocity (v). Velocity is the rate of change of position (s) of an object. The rate of change of a quantity is equal to the amount of change of the quantity divided by the amount of time that change required.

Suppose an object were at position s_0 at time t_0, position s_1 at time t_1, and at position s_2 at time t_2. The average velocity during the time from t_0 until t_1 and from t_1 until t_2 would be

$$v_1 = \frac{s_1 - s_0}{t_1 - t_0} \qquad and \qquad v_2 = \frac{s_2 - s_1}{t_2 - t_1} \quad \textbf{(EQ 4)}$$

The average acceleration can be determined from the average accelerations

$$a = \frac{v_2 - v_1}{t_2 - t_1} \quad \textbf{(EQ 5)}$$

These are only average velocities and accelerations, since the velocity will be changing during that time. The smaller the time interval considered the closer your calculated velocity is to the exact velocity at which you were moving during that interval. Instantaneous velocity is the velocity which would be calculated if an extremely small (nearly zero) time interval were used.

COMPUTER SKILLS

1. Connect the LabPro unit to its power supply and use a USB cable to connect it to the computer. A solid green light should be on in the LabPro.
2. Connect the Motion Detector with a cable to the DIG/SONIC 1 port of the LabPro. The switch under the sensor on the Motion Detector should be in the "cart" position.
3. Use the icon on the computer to start Logger Pro. The green light on the LabPro should be flashing.There should be a table on the left and graphs on the right of the screen.
4. To change the shape of a graph click on it and use the handles on the top, bottom and sides to shrink or enlarge it. To move a graph hold the left mouse button down when the finger pointer is showing and drag the graph. To add a graph click on the **Insert** tab and select **Graph**. To automatically place the graph with others already displayed, click on the **Page** tab and select **Auto arrange**.
5. Use the instructions in step 4 to create three graphs. For person A and C the three graphs from top to bottom should be for position, velocity and acceleration. For person B the graphs should be in reverse order.
6. Set the track level on the table, attach the flag to the magnet on top of the cart, and place the cart on the track at one end. Place the Motion Detector at the other end with the sensor up and facing the flag of the cart.

7. Keep your arm or any other object out of the space between the cart and the detector. Press the collect button on Logger Pro and wait for a clicking sound to begin.
8. As soon as the clicking sound begins, gently push the cart towards the detector. If it slows down nudge it again. You should have five seconds from when the clicking starts to move the cart.
9. Right click on each graph and select **graph options**, select the tab **axes options**, and confirm that the scaling is set to **auto scale** for both the x and y axes. There is also a direct auto scale feature available on each graph.
10. Repeat steps 7 and 8 one more time after using auto scale.
11. Open a Word document and enter the proper title information.
12. Create a header titled Logger Pro Test. and write a paragraph describing the way you set up and pushed the cart.
13. In Logger Pro right click on the top graph and select **copy**. In the Word document click paste and the graph should appear there. Repeat for each of the other two graphs and add a caption to each graph.
14. From the **File** tab on Logger Pro select the **Export As** menu and the **CSV** option. IN the dialog box save the file as type .csv in a directory where you can find it.
15. Start Excel and click on the cell A1 in the upper left corner. From the **Data** tab click on **From Text** in the **Get External Data** box. Find your .csv file and double click on it. In the dialog box click on **Next** then check the box for **Comma**. Type **Finish** then **OK**. The Logger Pro table should now be in Excel.
16. Select and delete all the Excel rows after a time of 1 sec which should be in row 21. Leave a blank row at the bottom of the data and then type average acceleration in column A. In the same row in column D type **=(C21-C2)/(A21-A2)** then enter and a number will appear in the cell.
17. Format the data into a table and copy the table and your extra calculation into your Word file.
18. Let the TA check you on your work (each member must do this separately).
19. Save the file as the first part of your report.

DATA COLLECTION

1. Start a new Word document for your report with the heading *Data Collection*. This only needs to be done once for each group. Briefly describe your track and draw a simple diagram in your report. You do not need to copy or repeat all the information from the handout, but you should cite the handout in this description as a reference. A group may work on the joint text parts of the report outside of lab.
2. Set the height at the high end of the track so that it is approximately 20 cm above the table. Measure the length (L) of the track between two points on the track. Measure the heights (h_1, h_2) of the track at the two points used to measure the length, but use the same surface top or bottom for both heights.
3. Place the detector at the top of the track. Practice gently sliding the cart up the track from the bottom so that it goes about halfway up the track. If it is pushed too hard it will derail, and it needs to be caught at the bottom. When the cart falls it can cause misalignment which increases friction.
4. Start data collection by clicking on the **collect** button on the software. Gently push the cart up the ramp when you hear a clicking sound and catch it at the bottom.

5. Review the graphs in Logger Pro. The position versus time graph should be a smooth parabola, and the velocity versus time graph should be a straight line. Repeat step 3 until both curves are reasonable, and check with the TA to verify that they are.
6. Write a description of your data collection up to now. Include the measurements of the track in step 1. Mention how many practice pushes you made in part 2 and how many trials you took in part 4 to get approved graphs. Use enough text so that the report is easy to read with complete sentences and paragraphs.
7. Copy the graphs from Logger Pro into your report and create a table from the Logger Pro data by copying to Excel then into the report. As always include captions, but also add enough text so that the source of the graphs and table are clear to the reader.
8. Repeat steps 2 through 7 but with the high end about 15 cm above the table. Place the data table on a new sheet in Excel by clicking on the **Sheet2** tab at the bottom of the spreadsheet.
9. Repeat steps 2 through 7 but with the high end about 10 cm above the table. Place the data table on **Sheet3** in Excel.

DATA ANALYSIS

10. Start a new section in the report with the heading *Data Analysis*.
11. For the first incline position, identify a stretch of data that corresponds to a region where the velocity graph is nearly a straight line with constant slope.
12. Find the times that correspond to the beginning and end of the stretch of data identified in step 10. Use EQ 5 to find the average acceleration during that time interval.
13. Use EQ 3 to find the expected value of a for each set of data.
14. Add a paragraph in your report describing the interval you selected on the graph, the average acceleration from step 11 and the expected acceleration from step 12.
15. Repeat steps 11 through 13 for the other two sets of data.
16. Your TA will assign an addition question or two to answer in the report. This work should be done by each group member individually.
17. Each student should assemble a single report from the computer exercise, the group data report and the additional individual question. This report will be turned in for grading.