Description

In this lab coffee filters will be used along with Pasco Capstone software to determine the value of the air resistive constant of a coffee filter. Generally the equation for a small object that is not travelling at high velocities is represented by the equation $F_{\text{air}} = kv$. This equation means that the resistive force that air provides on an object depends on the velocity which it travels at along with a constant that is related to the surface area and volume of the exposed object. The general setup will involve a stand where a Pasco Motion Sensor II will be attached to the top of the stand while coffee filters are dropped below it to display graphs of position, velocity, and acceleration on the Pasco software.

Materials

- Pasco Capstone Software
- Coffee Filters (4 minimum)
- Stand With Rod Through Center
- Metal Clamps
- Pasco Motion Sensor II
- Textbooks (Optional)
- Scale (To Measure Mass)

Procedure

1. Start by setting up a firm heavy stand with a rod through it and place a clamp that can attach to two rods. After attaching the clamp on one side to the rod going through the stand, attach a rod of equal or shorter length to the other end of the clamp in a manner such that both rods make a 90 degree angle. A picture is provided to demonstrate exactly how it should appear in the end as well as a picture of the clamp itself.
2. Now grab the Motion Sensor II and there should be something to unscrew on the side of the sensor. Unscrew it but not all the way and notice that there is a hole through the lower part of the sensor so now push the rod attached perpendicularly in the previous step through the hole in the lower part of the sensor. Push the sensor just enough so it is exposed through the other side and screw the sensor into place in such a position that allows the sensor to face the ground as shown above.

3. After setting this station up open up the Pasco Capstone Software on the computer and click and drag graph and table onto the main screen. After doing so the Motion Sensor II must now be set up with the software to do so connect the two wires to the Pasco machine. It doesn’t matter which two ports it is plugged into as long as they are next to each other and yellow is on the left and black on the right. Next right click on Hardware Setup in the software and on the diagram of the Pasco Machine click on the ports which were used to plug in the sensor. Go under add a sensor and scroll till reaching Motion Sensor II and click on it.

4. If step 3 was done correctly then in the Pasco Machine Diagram there should be lines pointing to ports in which sensor was plugged in that are green NOT orange. If the lines are orange retrace your steps and ask your teacher for assistance till they turn green as shown below.

5. Before beginning actual trials go to Data Collection and with your group make predictions for Graph 1.1 through Graph 1.6. Make sure that you discuss within
your group on a general unified idea of how the graphs should appear before continuing.

6. Now that the sensor has been connected properly the software trials may begin. To do a trial start off with desired number of coffee filters (First it is best to use one) and have one person hold it right below the sensor pointing to the ground as pictured in Figure 1.1 with the stand on the ground. Make sure that the person holding it is steady and ready for the signal of a person at the computer to begin recording data.

7. The person at the computer must make sure that in the table in Pasco Software is presenting velocity and time as well as the graph of velocity vs time to start off with. Once the person is ready press record and be aware of the starting velocity which should be 0. Give some kind of signal to let the person know who does the dropping that he or she can now drop it releasing grip of both hands at the same time ensuring for a straight steady downward fall. After reaching the ground the person at the computer should stop the recording and gather the group to make observations of the data.

8. Repeat step 7 a few times till a graph that is not too “shaky” is observed and one that everyone in the group feels comfortable with. Use the trial that seems the least “shaky” to sketch a graph of the actual observed data in Graph 1.5.

9. Now go onto the Pasco Capstone Software and change the data being observed from velocity to position and record the least “shaky” run from the velocity trials to record the actual data into Graph 1.4. Next change the data being observed to acceleration and record the least “shaky” run from the velocity trials to record the actual data into Graph 1.6.

10. Repeat steps 7 through 9 but now instead use two coffee filters and when recording data into graphs make sure to make each graph differentiable so it is known which is prediction, 1 filter, and 2 filters. Do you notice anything strange in the data? If so place stand on a table and let coffee filter drop all the way to the ground repeating steps 7 through 9.

11. Repeat step 10 but with 3 coffee filters and if data seems strange then place the stand on an even higher surface. Why does the height matter?

12. \( V_T \) is the highest value of velocity that each of the trials should reach, and where the velocity graph is a near horizontal line. Keep this in mind for step 13.

13. After successfully completing steps 1 through 11 go into the Pasco Capstone Software and in the data table of your first non “shaky” trial used for the Graph of 1.5 add a calculation column by pressing the button at the top of table with a calculator symbol. Now a line will be prompted with Calc1 = , where the equation of \( \text{LN}(1-(\text{Velocity} \text{m/s})/V_T) \) will be entered. To enter the LN function right click in equation box and go under function, scientific, and choose LN. To input the Velocity data right click and go under Data and choose velocity. After being entered press enter on the keyboard and the column should display these calculations, but what do they represent? If you were told that the equation for velocity was \( v = v_T(1-e^{-kt/m}) \), which can be easily solved for with Figure 1.1 would you be able to solve for the calculation.

14. After successfully having values in the new Calculation column of the table go to the graph portion and graph Calc1 vs Time. A portion of the graph should be a
straight line why is that? What does the slope represent use the equation in step 13 to figure it out? Find the slope using the slope tool and multiply the slope by the mass of one coffee filter measured by a scale. Record this value into Table 1.1 in Data Collection under the velocity column with 1 filter and with no unit of measurement.

15. Repeat step 14 except use the best non “shaky” trial with two coffee filters and then do the same with three coffee filters.

16. Now using the equation \( v = v_0(1-e^{-kt/m}) \) can your group derive an equation for acceleration. Once derived find what \( \ln(\text{Acceleration} \ \text{m/s}^2) \) is equal to using derived equation is this value the same value as from what \( \ln(1-[(\text{Velocity} \ \text{m/s})/V_0]) \) equals. If you do see that they are the same values then repeat steps 13 through 14 with entering \( \ln(\text{Acceleration} \ \text{m/s}^2) \) into Calc1 and record the values into the column under acceleration. If at any times the graphs seem to be too “shaky” use of the smooth tool may help but use in moderation.

Data Collection

**Graph 1.1 Position**

*Prediction Without Air*

<table>
<thead>
<tr>
<th>Position</th>
<th>Time</th>
</tr>
</thead>
</table>

**Graph 1.2 Velocity**

*Prediction Without Air*

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Time</th>
</tr>
</thead>
</table>

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Graph 1.3 Acceleration Prediction Without Air Resistance

Graph 1.4 Position (Prediction and Actual Results) With Air Resistance

(Graph 1.5 Velocity With Air Resistance (Prediction and Actual Results))
Graph 1.6 Acceleration With Air Resistance (Prediction and Actual Results)

Table 1.1 Recording Unknown Calculated Values

<table>
<thead>
<tr>
<th>Filter(s)</th>
<th>Velocity</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Filter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Filter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Filter(s)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis

1. What kind of functions each the graphs of the actual data you sketched in the Data Collection? (logarithmic, parabolic, hyperbolic, etc.)
2. Why if at all were your predictions different from the actual sketched data? Could you explain these differences?

3. How does the actual data graphs with air resistance compare to the predicted graphs without air resistance? How do they differ?

4. Even after many trials were there any noticeable “shakes” in the graph such as a strong upward then downward line that then returns to a normal state? If so discuss with groups and teacher as to why this might happen?

5. What are the values in Table 1.1 representing and if there is a similarity in the values explain why? What were \( \ln(1 - (\text{Velocity} \, m/s) / V_T) \) and \( \ln(\text{Acceleration} \, m/s^2) \) equal to and why was mass divided to record values in Table 1.1?

6. Why should the smooth tool be used in moderation what happens when it is used in excess? Why is it that when a filter seems to drop directly straight down there may still be small spikes in the graph?

7. Could the same calculation that was solved for with acceleration and velocity that turned out to be the same value for both be made with an equation for position? If it can be done attempt to input this equation into the Calc1 Data Table in the Pasco Capstone Software? Explain your results with position and why they did or did not work?