Motion 2

<u>Equipment</u> Capstone, motion sensor, meter stick, air track+ 2 gliders, 2 blocks, and index cards.

<u>Air Tracks</u> In this experiment you will be using an air track. This is a long straight triangular like beam that has many small holes in it. A blower pumps air through the holes. A glider placed on top of the air track floats on a cushion of air with low friction. The blower sits on the floor and has a variable adjustment screw for the airflow. The blowers are noisy and run hot. Run them only when you need them.

   Please handle the gliders carefully. They are expensive, and if dropped or abused they will not work well. Do not move the gliders on the air track without the blower on, as this will wear both the glider and air track. A motion sensor is used to detect the gliders, the gliders will have a piece of index card at one end to reflect the sonic pulses or a metal plate that gets mounted on top of the glider. **Orientate the metal plate or index card towards the motion sensor.**

1   Purpose

To study the relationships between position (x), velocity (v), acceleration (a), and time (t). In general, x, v, and a are vectors but we specialize them to one dimensional case where we may treat them as scalars. We also make the special assumption that a is a constant (In general, a may be a function of position and/or velocity and/or time).

2   Theory

The velocity v is defined as $v = \frac{dx}{dt}$ and acceleration as $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$. If this last definition is integrated twice over time for a=constant, the two integrations yield

$$x = x_0 + v_0 t + \frac{1}{2}at^2, \ and$$

$$v = v_0 + at.$$

The constants x_0 and v_0 are the position and velocity when $t = 0$. The first equation is a parabola and the second a straight line. If these equations are graphed, by convention, time is chosen as the horizontal axis and position and velocity as the vertical axes.

3   Part 1: Position, Velocity, Constant Acceleration

The motion sensor is used to measure the position of a glider on a tilted air track as a function of time. If there were no friction, Newton's 2nd law predicts that the acceleration of the glider would be $g \cdot \sin\theta$, where g is the acceleration of gravity and θ is the angle between the air track and the horizontal. Capstone calculates the velocity and acceleration from the position vs. time data.**How will acceleration change when we double the mass of the glider? Explain.**

3.1   Setting up the experiment

- Check the motion sensor is plugged into two digital ports. After program Capstone for the digital motion sensor (Motion Sensor II). Use the default sample rate and speed of sound.

- Level the air track by turning on the blower, place a glider on the track. Use the adjusting screw at one end of the air track so that the glider does not move along the air track.

- On the bottom within the under center of air track measure distance between the single supporting screw and the line formed by the two supporting screws at the other end.

- Measure the thickness of the two blocks of wood with a meter stick and then raise the end of the air track near the mounted motion sensor with the thinner block. Next calculate θ of each block.

- Drag and drop the graph icon from the displays box to the center of the white screen to create a graph. (To fit the graph on screen click on the orange thumb tack.) Click on the **Select Measurement** tab and choose position.
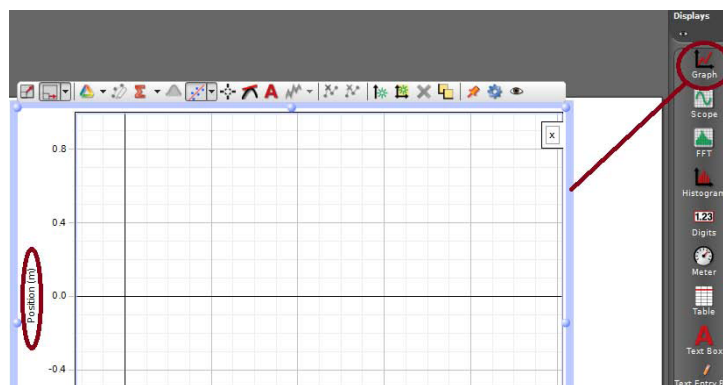
    The y-axis should now read position and the x- axis will read the default, time.

- Do the same for the **velocity vs time** and the **acceleration vs time** graphs.

    You should now have three different graphs, one for each of the three quantities. Note: Reminder use the overlapping button which is the orange tack on the hardware setup window if the screens are overlapping.

3.2   Running the experiment

- Place the motion sensor near the spring bumper at the high end of the air track so that the grill looks down the track.

- Position the card on top of the glider to allow the motion sensor to detect the glider.

- The motion sensor does not work for less than 0.2 m, so place an object under the air track 0.2 m from the sensor and start your gliders from that point.

- Turn on the blower

- Place the smaller glider on the track, release the glider and click the **Record** button at the same time. The record button is located at the bottom left of the Capstone screen.

- Click **Stop** just before the glider hits the end of the air track.

After each run check your data and if needed make small adjustments in the orientation of the motion sensor until you get smooth data points on the graph. You will probably find that if the sensor points slightly up the data will be best.

3.3   Using the graphs

Click on the **Data Summary** icon and select the best data run. On each graph click the scale to fit button (located on top left of the graph with the red arrow pointing at an angle) and examine the three graphs in the display. **Explain whats occurring in each vector and why?** You can adjust the scale of your graphs by clicking and holding on the axis you want to adjust in the graph display. Zoom in on the acceleration graph and highlight around the data points you would like to analyze. Try to highlight each graph so that they all begin and end at the same times.
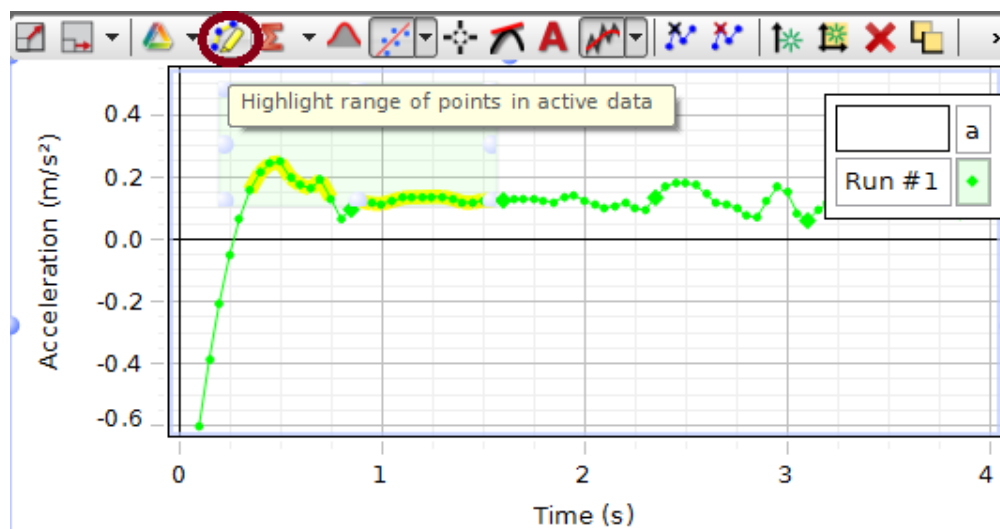
You also have an option to reduce the noise in the data by adjusting using smoothing scale. This will help for the acceleration curve. Just don't overuse this option!
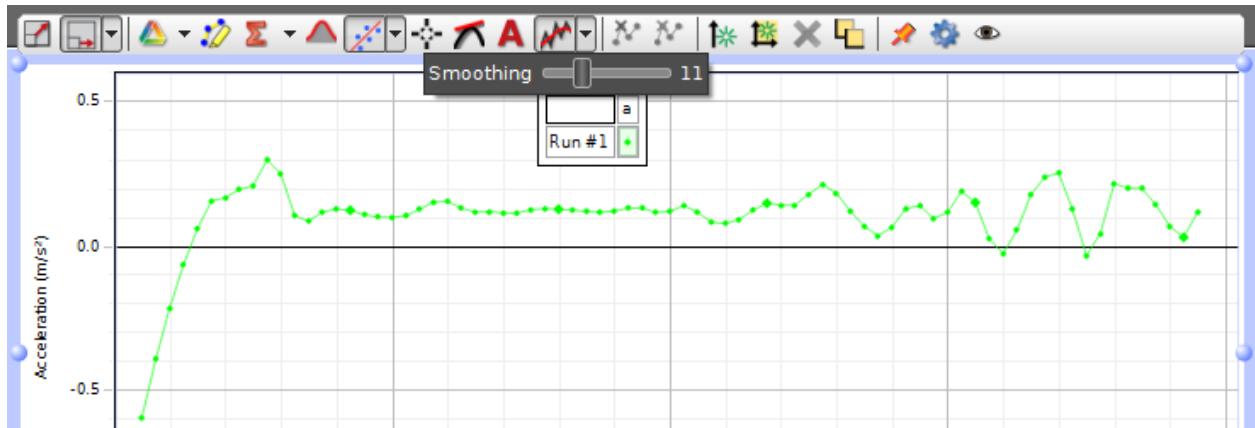

Do the graphs illustrate what is predicted by the theory? How so and explain! What are the correlations of all the graphs? The velocity curve is noisier than the position curve, and acceleration curve is noisier than velocity curve. Why?

Next, you will analyze each graph by fitting a curve to each graph. This will be done clicking on the little down arrow of the select curve button on each graph.
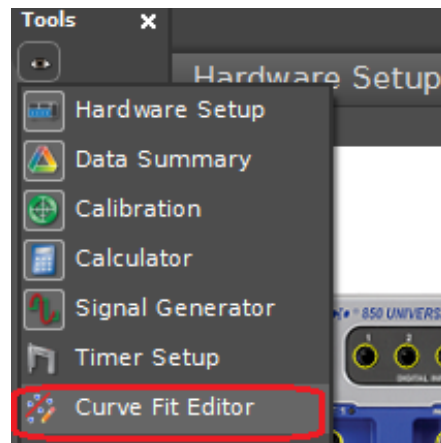
For the position graph click on small down arrow and scroll down to select **Power** .
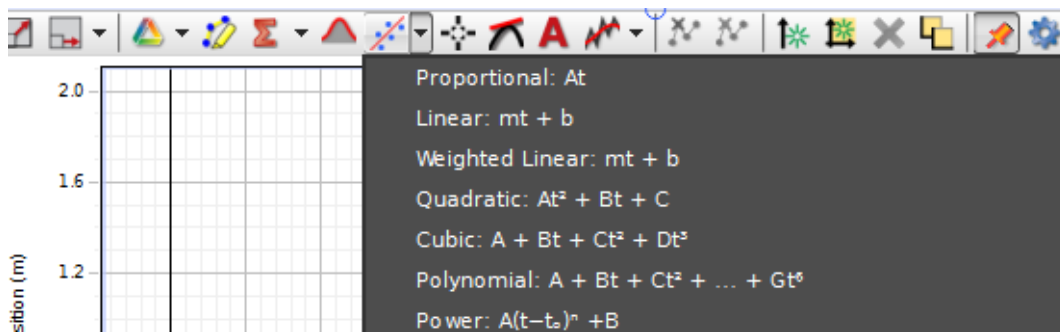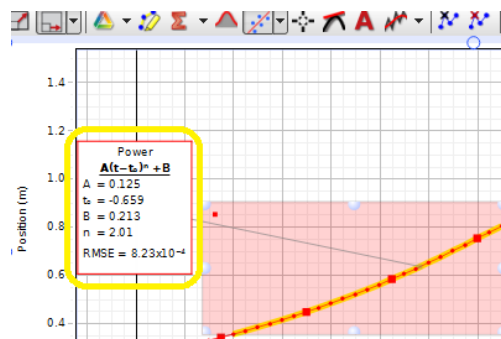

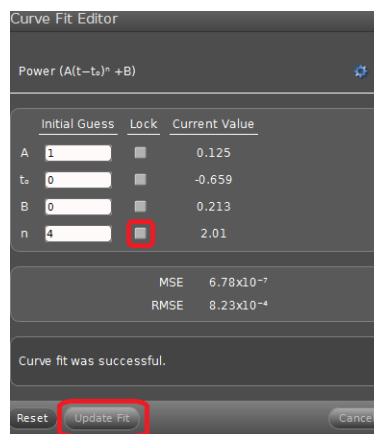Next, click on the center of the curve button.
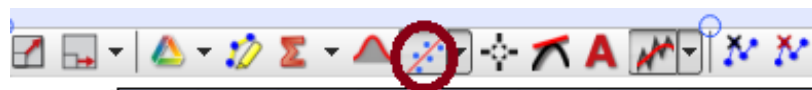
After, you have to adjust the settings of the power fit function. Go to **tools** and click on the small eye. Scroll down and select **Curve Fit Editor**. A curve fit button will come up under the tools column.


In the **Tools** column click on the curve fit editor button and then go to the position graph and click on the power box.


A **Curve Fit Editor** window will come up. Make sure the lock box in the **n** row is unchecked. If not then uncheck that row and click on **Update Fit**.

Next, you will setup the velocity graph for a linear function. Go to the velocity graph click on the small down arrow and choose **Linear**. Click on the center of the curve button.
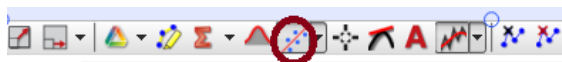
In the acceleration graph you can analyze the **Mean** y average value by clicking on the sigma button located on top of the graph.
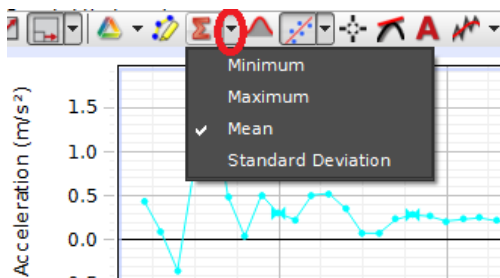
- First, you need to Select the small black arrow next to sigma and select mean.

- Select mean

- Click on center of the Σ button to show mean value.

If your data points are noisy near the ends, highlight the best parts of the curve to exclude the noisy data but include as much good data as possible. **Try to highlight each graph so that they all begin and end at the same times. For the velocity plot the acceleration is given by the slope (m). Why?** Explain. In the acceleration plot the average acceleration for the data in the box is given by the mean of (y). Compare this to the slope (m).

Note: To increase the number of digits to the right of the decimal point for the mean value of acceleration you have to open the data summary window. Illustrated below
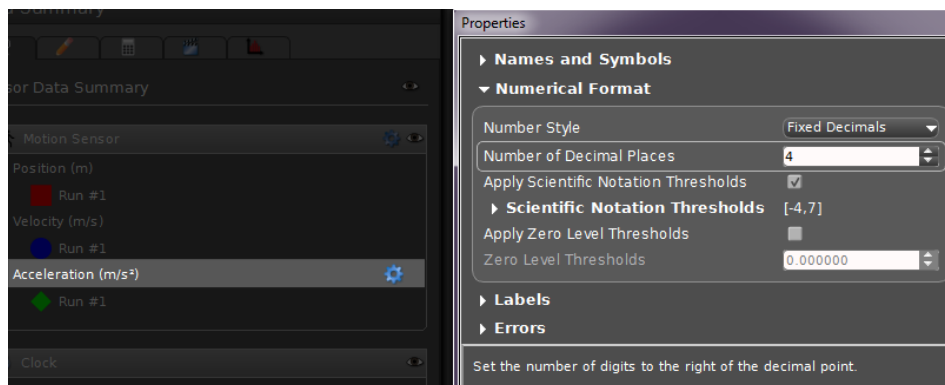
To see the data summary window click on the data summary button in the tools column. Scroll and click on acceleration. Then click on the gear icon. A properties window will come pop up. Click on numerical format and adjust the number of decimal points. Increase the number of digits to at least three digits.

3.3.1   Questions

For the position plot, the notation n(Power) means that the function is raised to a certain exponent. **What is your experiential n(power)? What does theory say it should be? Why is there is a difference?**

3.4   Two different masses and θ Dependence

In the following experiments, use (m) as a measure of the glider acceleration. Determine (m) for a reasonable amount of data using the previous procedures. (m) is referencing the slope of the velocity graph.

Measure the acceleration for a glider of different mass for the same θ. Then change the θ by substituting the thicker block and measure the acceleration for the two different masses. Do this five times and get statistics. Compare and discuss your results. Compare to the theory. **When the same θ is used for the different gliders is there a difference in acceleration? Why?**

4   Part 2

4.1   A Bigger Picture and Dissipation

Do the following for only one mass and one θ. Follow the procedures above except let the glider hit the end of the air track 3 times before clicking the stop button. Discuss your graphs and results. Point out where on your graphs the glider hits the end of the air track. **Does the velocity curve cross the axis (velocity=0) where you expect it to? Are the curves the same from bounce to bounce? If not, could you suggest why?** Print out the best graph and explain what is occurring to the glider position, velocity, and acceleration before and after the collisions.

5   Shut off the air blower and place the equipment back as you found it!