# Lab 03: Constant Acceleration

INTRODUCTION

Galileo is very famous for inventing the telescope, and the subsequent observations he made with it. He's a little less famous for the experiments that he performed using inclined planes, but these experiments set the stage for Isaac Newton and his very famous Laws of Motion. Galileo's careful experiments were the first to clearly demonstrate the kinematic relationships that we now accept as, well, pretty obvious. Notice that, even though they did not have digital stopwatches or computerized data collection in the 17th century, a pendulum clock provided accurate timekeeping. Reproducing Galileo's experiment is easy, and since we do have accurate data collection methods, we won't have to count the pendulum swings.

Not literally Galileo, but a pretty accurate representation of the device he used to measure constant acceleration.

OBJECTIVES

- ◉ Verify Galileo's observation that an object on an incline will move with a constant acceleration
- ◉ Confirm graphically the kinematic relationship between distance traveled and elapsed time
- ◉ Determine the acceleration of an object down an incline, and relate it to the slope of the ramp
- ◉ Compare the accelerations of uphill and downhill motions

EQUIPMENT

- ◉ LabQuest unit
- ◉ Photogate
- ◉ Dynamics track & cart
- ◉ Angle indicator

Please do not let the dynamics cart crash into the bumper repeatedly!
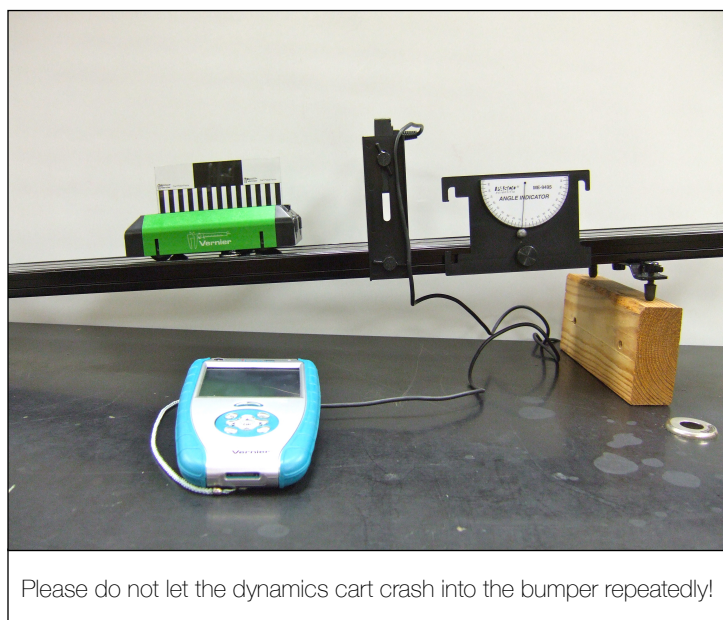
PROCEDURE

◉ Mount both the photogate and the angle indicator to the groove on the side of the dynamics track. Mount the magnetic repulsion bumper to the opposite end of the track, as shown in the figure. Raise the end of the track to create a ramp, and record the angle of the incline.

◉ Plug the photogate into the **DIG 1** channel of the LabQuest. When you switch on the LabQuest, it will not automatically find the gate. Under the **Meter** tab, select the **Sensor** menu and choose **Sensor Setup**. From the drop-down list, select **Photogate** for **DIG 1** and tap **OK**.

◉ Choose **Data Collection** from under the **Sensor** menu. The unit is in **Photogate Timing** mode, but now you will toggle the **User Defined** button. With the stylus, swipe the numeric value to highlight it, and when the keyboard pops up, change the value to **0.01** (and tap **OK**). This change is necessary, since the smaller picket fence for the cart has a different spacing than the default value.

◉ Snap the small picket fence onto the dynamics cart, and place it on the track above the gate. Adjust the height of the photogate to insure that the small pickets will break the beam.

◉ Switch to the **Graph** tab. You should see two plots: **Graph 1** is **Distance vs time** and **Graph 2** is **Velocity vs time**.

◉ When one person taps the **Go** button to begin data collection, another person should release the cart form rest, so that it travels down the incline through the photogate. The LabQuest will collect and display the same position and velocity data as previously.

◉ Release the cart form rest three times, making sure to save each trial by tapping the **File Cabinet** icon.

◉ Perform another three trials, but begin with the cart **below** the photogate. When one person starts the data collection, another should give the cart enough of a push to send it **up** the incline and through the photogate. Catch the cart before it heads back down the ramp. Make sure to save each of your trials, so that you can refer to them afterwards.

DATA

DOWNHILL	d vs t: Coefficient A	$a = 2A$ (m/s²)	a = Slope of v vs t (m/s²)	average a (m/s²)
RUN 1				
RUN 2				

DOWNHILL	d vs t: Coefficient A	a = 2A (m/s²)	a = Slope of v vs t (m/s²)	average a (m/s²)
RUN 3				

UPHILL	d vs t: Coefficient A	a = 2A (m/s²)	a = Slope of v vs t (m/s²)	average a (m/s²)
RUN 4				
RUN 5				
RUN 6				

ANALYSIS

1. For each of the data trials, perform a curve fit on the position vs time curve. According to our kinematic equation
$$x = v_o t + \frac{1}{2}at^2$$
the graph should not be a line. In your notebook, sketch the shape of the curve and write down the equation which best fits the curve. In this case, make sure to record the coefficient "A" of the quadratic (squared) term. You will use this coefficient to calculate the value of the acceleration of the cart.

2. For each of the trials, also fit the velocity vs time graph with a line. According to our kinematic equation,
$$v = v_o + at$$
the slope of the line represents the acceleration of the object. Record the equation of each line in your notebook.

3. If you have not yet, make a neat table to summarize your results for these trials. An example is shown above.

4. You should have six separate values for the acceleration downhill, and six more for the uphill trials. Calculate an average for the downhill trials, and another for the uphill trials.

5. Record the shapes of the distance vs time and velocity vs time graphs in your notebook. Compare the shapes of these graphs to the free fall graphs. The values are not the same, but are the curves shaped similarly?

6. Fit each of the velocity vs time curves with a line. Record the slopes, which again represent the acceleration. Calculate the average acceleration for the downhill data, and another average for the uphill data.

7. Compare the average downhill and uphill accelerations. Are they the same? Should they be? Explain why the uphill trials result in a negative value for the acceleration.

8. The acceleration of an object on an incline is predicted to be:
$$a = g \sin \theta,$$
where $g = 9.8$ m/s² and θ is the measured angle of the incline. Calculate this predicted value, and compare your **average downhill acceleration** to the prediction by computing the percent error:
$$\% \, error = \left(\frac{prediction - average}{prediction} \right) \times 100$$

9. What are some (different) reasons why your experimental value does not exactly match the prediction? How could you either improve the measurements, or improve the prediction?

10. If the acceleration depends on the incline angle, what happens if you increase the slope of the ramp? What would be the steepest incline you could have, and what would be the resulting acceleration?

11. Refer back to your distance vs time and velocity vs time graphs, and think about constructing a third plot. What would a graph of acceleration (*y*-axis) vs time (*x*-axis) look like for your data?

12. Examine the position vs time plot shown on the right. How does this differ from the graphs of your data? Sketch your prediction for the velocity vs time graph. What is the acceleration of this object?

Position vs time / Velocity vs time

This is *not* actual data, but your curves should have the same shape.

Position vs Time