

Acceleration of a Cart on an Inclined Plane

| Equipment Needed | Qty | Equipment Needed | Qty |
|-----------------------|-----|-------------------------------|-----|
| Photogate and Bracket | 1 | Dynamics Cart (inc. w/ Track) | 1 |
| Bumper | 1 | Ruler | 1 |
| Base and Support Rod | 1 | 1.2 m Track System (ME-9429A) | 1 |

What Do You Think?

What happens to the acceleration of a cart as it moves up and down an inclined plane?

Background

If a cart moves on a plane that is inclined at an angle θ , the component of the gravitational force acting on the cart in a direction that is parallel to the surface of the plane is $mg\sin\theta$, where m is the mass of the cart and g is the acceleration due to gravity. The acceleration of the cart, in the absence of friction, should be $g\sin\theta$, both up and down the inclined plane. The acceleration is not expected to depend on the mass of the cart.

For You To Do

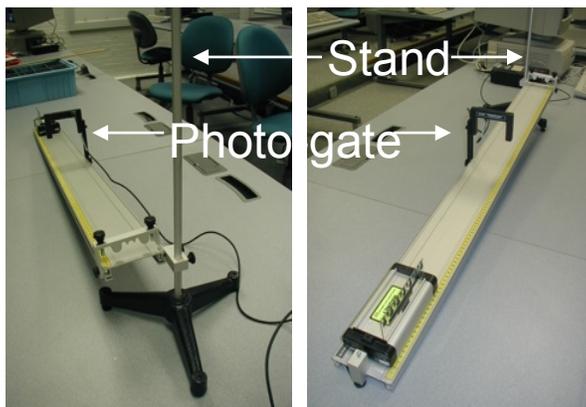
Use a motion sensor to measure the motion of a cart that is pushed up and down an inclined plane. Use *Capstone* to record the motion and calculate the velocity and acceleration of the cart as it moves up and down the inclined plane. Compare the measured acceleration with the theoretical estimate. Compare the acceleration measured for motion up the incline with the acceleration measured for motion down the incline. How does the measured acceleration depend on the mass of the cart?

PART I: Computer Setup

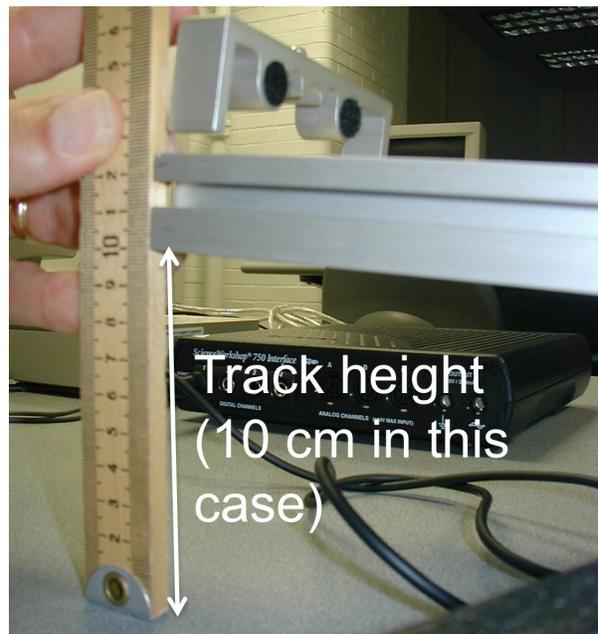
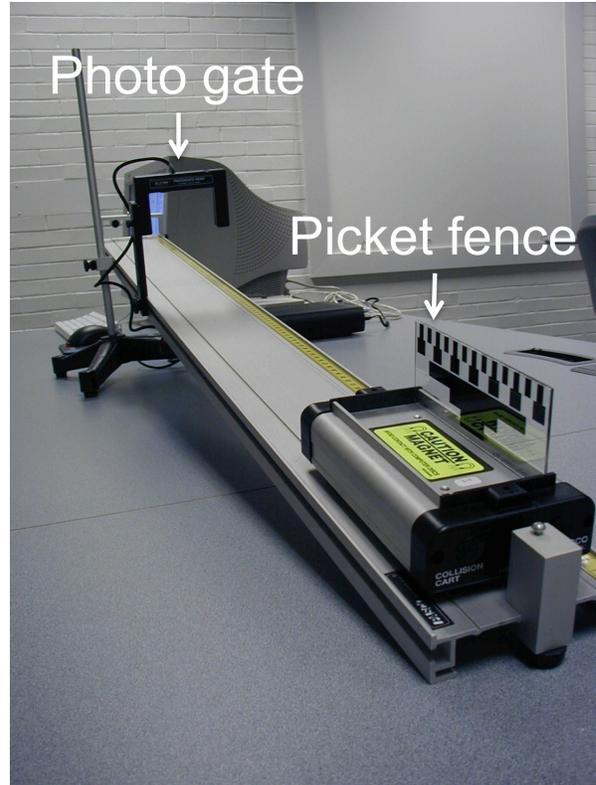
1. Make sure that the *ScienceWorkshop* interface is connected to the computer and turned on (look for the green light on the front panel of the interface).
2. Connect the photogate's stereo phone plug to Digital Channel 1 of the interface.
3. Download the setup file *InclinedPlane.cap.zip* for this measurement from the Physics 141 web site (select Laboratories -> Lab 1 from the toolbar). The setup file will be downloaded as a zip file.
4. Open the *Capstone* program by clicking on the icon in the Dock.
5. After the program opens, select the "Open Experiment" option from either the top toolbar or the "File" menu and navigate to your desktop to open the document entitled *InclinedPlane.cap* that was downloaded from the Physics 141 web site.
6. The *Capstone* document opens with a graph display that shows the measured velocity versus time.
7. Before proceeding, select "Save As" from the file menu to ensure that you can save the data you will collect. Use a new filename that clearly identifies this file as belonging to you (e.g. I may use the filename *InclinedPlaneFW101507.cap*.)
8. **Make sure that you save your work frequently so that you do not lose any large amount of data if computing problems occur.**

**PART II: Sensor Calibration and Equipment Setup**

1. You do not need to calibrate the sensors for this activity.
2. Place the track on a horizontal surface. If not installed, mount a bumper on the open end of the track.
3. Mount the photogate on the track and connect the track to the support rod.



4. Put the picket fence in the proper slots on the top of the cart and adjust the height of the photogate to ensure that the light is hitting the proper series of bands; for this experiment we will use the top series of bands. Note: you can verify proper operation of the photogate by moving the cart by hand through the photogate and observing the red light on top of the photogate turning on and off. The light turns on when the photogate beam is intercepted and this light should follow the pattern of bands you plan to use.
5. Measure the spacing between the opaque bands on the picket fence. To change the default setting to another value, select “Hardware Setup” from the left toolbar, click on the picture of the photogate and then on then click on the photogate “Properties” symbol. A window will open that will allow you to change the “Flag Spacing.” Note that the spacing is measured in meters. Enter the correct value for the spacing of the opaque bands on your picket fence and click OK.
6. Raise one end of the track by 10 cm. Make sure you record the actual height since you will need it to determine the angle of inclination.



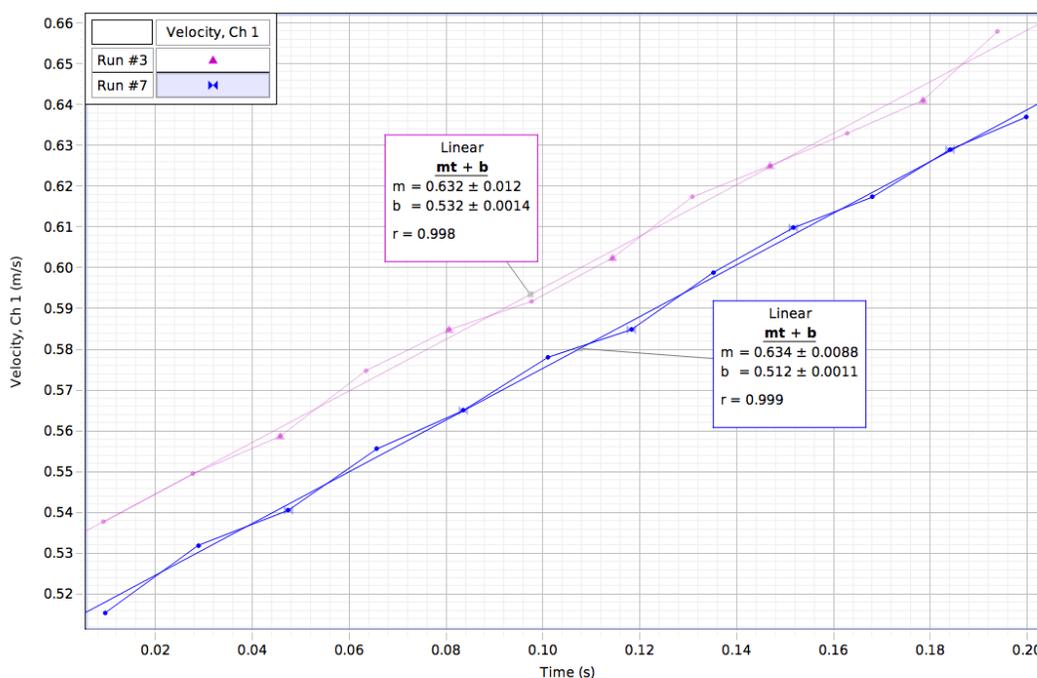
Preparing to Record Data

1. Before recording any data for later analysis, experiment with the photogate to make sure it is aligned and can “see” the cart as it moves.
2. Put the cart at the top of the track and let it go; make sure you lab partner stops the cart before it hits the stop at the bottom of the track.
3. Position the cart at the bottom of the track and give it a quick push such that it passes through the photogate on its way up the track, comes to rest, and passes for a second time through the photogate on its way down the track.

- When you feel comfortable with the procedure, position the cart at the bottom of the track, start recording data, and give the cart a push so that it carries out the motion describes in step 3.
- Stop recording when the cart returns to the bottom of the track.
- Examine the data collected and determine if you understand your observations. Make sure that you determine if the number of data points is consistent with the number of bands you are using for this measurement.

PART III: Data Recording

- With one end of the track raised by 10 cm, hold the cart at the top of the track so that it is in contact with the bumper.
- When everything is ready, start recording data. Release the cart and make sure you stop it before it hits the stop at the bottom of the track.
- Stop recording and determine the acceleration of the cart. The acceleration of the cart can be obtained from the measured velocity versus time graph. In *Capstone*, click on the  button. This is the fit menu. From this menu, select the “Linear: $mx + b$ ” fit. You can do a linear fit to several data sets in a single graph by selecting the proper run in the legend before selecting the fit. In the Figure below, the last fit carried out used the data from Run #7. Note: if you try to apply a linear fit and a message appears saying “curve fit status value contains an unexpected value,” then either try to change the initial guesses for m and b in the curve fit editor (located on the left toolbar) or use the weighted linear fit.



4. Repeat steps 1 - 3 ten times and determine the average acceleration of the cart when it moves down the incline (**include an error estimate**).
5. Make a quick comparison between the measured acceleration and the theoretical acceleration.
6. Repeat steps 1 - 5 after increasing the mass of the cart. Is the acceleration of the heavier cart different from the acceleration of the original cart?
7. Remove the mass you added to the cart in step 6 and position the cart at the bottom of the track.
8. When everything is ready, start recording data. Give the cart a quick push such that it passes through the photogate on its way up the track, comes to rest, and passes for a second time through the photogate on its way down the track.
9. Stop recording and determine the acceleration of the cart when it moves up the incline and when it moves down the incline.
10. Repeat steps 7 - 9 ten times and determine the average acceleration of the cart when it moves up the incline and when it moves down the incline (**include an error estimate**).
11. Make a quick comparison between the two measured accelerations and the theoretical acceleration.
12. Set the track to a steeper angle by increasing the height of its raised end by 5 cm. Repeat steps 7 - 11.
13. Set the track to an even steeper angle by increasing the height of its raised end by an additional 5 cm. Repeat steps 7 - 11.

Record all your results in the Laboratory Data Sheet section.

Laboratory Data Sheets - Acceleration of a Cart on an Inclined Plane

| Run # | h (cm) | M (kg) | Slope (m/s ²) | Error (m/s ²) |
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| Average | | | | |
| Error | | | | |

Data for cart moving down the inclined plane (raised by 10 cm).

| Run # | h (cm) | M (kg) | Slope (m/s ²) | Error (m/s ²) |
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| Average | | | | |
| Error | | | | |

Data for heavier cart moving down the inclined plane (raised by 10 cm).

| Run # | h (cm) | M (kg) | Slope (m/s ²) Up | Error (m/s ²) Up | Slope (m/s ²) Down | Error (m/s ²) Down |
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| Average Error | | | | | | |

Data for cart moving up and down the inclined plane (raised by 10 cm).

| Run # | h (cm) | M (kg) | Slope (m/s ²) Up | Error (m/s ²) Up | Slope (m/s ²) Down | Error (m/s ²) Down |
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| Average Error | | | | | | |

Data for cart moving up and down the inclined plane (raised by 15 cm).

| Run # | h (cm) | M (kg) | Slope (m/s ²) Up | Error (m/s ²) Up | Slope (m/s ²) Down | Error (m/s ²) Down |
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| Average | | | | | | |
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Data for cart moving up and down the inclined plane (raised by 20 cm).

Questions

1. Describe the position versus time plot of the Graph display for the cart moving up and down the incline. Can you extract any useful information from the time gap between "up" data and "down" data?
2. Describe the velocity versus time plot of the Graph display. How does the slope for the "up" data compare to the slope for the "down" data?
3. Describe the acceleration versus time plot of the Graph display. Is the acceleration for the "up" data consistent with the acceleration for the "down" data?
4. How does the acceleration determined from the velocity distribution compare to the mean value of acceleration from the plot of acceleration distribution?
5. How will friction between the cart and the track impact the results extracted from your data?

