

# ACCELERATION ALONG A RAMP

**OBJECTIVE:** To study the motion of an object traveling up and down a ramp in the absence of friction and drag forces. To measure the acceleration of such an object and see how the acceleration depends on the ramp angle.

**THEORY:** If an object falls straight down and air resistance is small, we found in the last experiment that it accelerates down at  $9.8 \text{ m/s}^2 = 980 \text{ cm/s}^2$ . If an object glides along a horizontal track that has negligible friction and air resistance is again small, we would expect that it would not accelerate ( $a = 0 \text{ m/s}^2$ ).

If that frictionless track is tilted at an angle, then we would expect an acceleration down the track at some value greater than  $0 \text{ m/s}^2$  but less than  $9.8 \text{ m/s}^2$ . We would also expect that this acceleration would depend on the angle,  $\theta$ , that we tilted the track. Can you think of different ways that the acceleration,  $a$ , might depend on the angle,  $\theta$ ? Remember that we do expect  $a = 0 \text{ m/s}^2$  at  $\theta = 0^\circ$  and  $a = 9.8 \text{ m/s}^2$  at  $\theta = 90^\circ$ .

$$a(\theta) = ???$$

In this experiment we will try to come up with an empirical (based on experimental data rather than theory) relationship for  $a(\theta)$ . We will develop the theory in the lecture class.

## PROCEDURE:

**To keep the noise level down, keep your air blower off except when you need to make a run.**

*A worksheet appears on the last page for you to record your results.*

### 1. GET AIR TRACK READY:

- a) Place a cart on the air track, and turn on the air blower. The cart should slide easily on the track.
- b) Now place the cart on the air track and release it so that it has essentially no speed. See if the cart drifts. Try this at various points. If it consistently drifts to one side or the other, you can raise or lower the air track by adjusting a base screw on the air track, but do this **only with the permission** and oversight of your instructor. Repeat the procedure until your cart has very little drift (which means the air track is now essentially level). Turn the air blower off when finished with this test.

### 2. GET COMPUTER READY:

- a) If the monitor is blank, press any key on the keyboard to activate the monitor. If the monitor is still blank, make sure the computer and the monitor are on.
- b) **Plug in** both photogates into the digital adapter (they probably already are). It doesn't matter which photogate is plugged into the number 1 socket. Plug the adapter into the USB link (it may already be plugged in). The 'Data Studio' application should automatically load and the '*Choose sensor or instrument*' window should open. (If the application does not load, double click on the Data Studio icon on the desktop. Select '*Create Experiment*'. Then open '*Choose sensor or instrument*' window. If that doesn't work, call the instructor.)
- c) Choose '**Photogate timing**'.

### 3. CHECK PHOTOGATE ACTIVITY & MEASURE LENGTHS:

- a) When a cart is inside the photogate, the red LED on the photogate should light up. Test each photogate by placing the cart inside the gate.
- b) Now determine the length of the cart by positioning it on the air track and using the distance scale that is on the track. Record this length. You will need it later.

### 4. CHECK TIMING OF PHOTOGATES:

- a) Click the '**Start**' button in the upper left of the window. Clicking Start will not start the actual timing, it only gets the computer ready to record the times that the cart passes through the gates. The timing clock will change from red to green. Ignore the time on the timing clock. When the clock is green, the photogates are ready to record the time when the cart is inside one of the photogates. If you press stop, the clock will turn red. When you press Start, the clock will turn green again and it will be ready to record the next run.
- b) Get your watch or a stopwatch ready to measure elapsed time.
- c) Get a cart ready to place in one of the gates.
- d) At the same time you place a cart in the gate, start your watch. Keep the cart in the detector for as close to exactly 10 seconds as you can, and then simultaneously remove the cart and stop your stopwatch. Check your time with the time displayed in the table. If the detector is correctly calibrated, your time and the computer's time should be close to the same. This is also a test of your reaction time when using stop watches.
- e) Test the other photogate. Its time will be displayed below the first gate's time.
- f) When done testing, click the '**Stop**' button.
- g) Click on the '**Experiment**' tab at the top of the main window and select '**Delete all data runs**' to remove the timing output.

### 5. PREPARE FOR RUN:

- a) Click on the '**Setup**' button in the upper left of the window.
- b) Click on the '**Measurements**' tab. The default choices of '**Time in gate**' and '**Time between gates**' should already be selected. In addition, select '**Velocity in gate**'.
- c) Click on the '**Constants**' tab. Enter the length of the cart in the '**Flag**' space. Note that the units are in meters, not centimeters.
- d) Close the '**Setup**' window.
- e) Click and drag '**Velocity in Gate (m/s)**' from the *Data* window to the *Table I* window. Now the time in each gate, the velocity of the cart through each gate, and the time between gates will be displayed.

## 6. MAKE A RUN WITH THE AIR TRACK HORIZONTAL &amp; CHECK CALCULATIONS:

- a) Click the '**Start**' button and turn the air blower on.
- b) Perform a run by pushing the cart from one end of the air track, letting it go through both gates and on to the other end. Stop it before it bounces and goes through a gate a third time. If not, you will have more timings displayed in your table that may confuse you.
- c) Click the '**Stop**' button and turn the air blower off.
- d) The data should be displayed in the *Table I* window. By default, the velocities are displayed with two digits. Locate the settings button on the table toolbar – it looks like a little table of rows and columns. **Increase the number of display digits** by clicking on the small down arrow next to the settings button and select '**Increase precision**'.
- e) Record the times in each gate, the time between the gates, and the velocities in each gate as well as the length of the cart you measured earlier.
- f) We will now check the computer's displayed velocities and, in the process, see how it is computing them. *How can we calculate and check the velocities in the gates?* Think of a way to do this with the given information and see if your values agree with the displayed values.
- g) We are now ready to calculate the acceleration of the cart. Think of a way to do this. Remember that the average acceleration is given by

$$a = \Delta v / \Delta t$$

*How do you find  $\Delta v$ ? What value should you use for  $\Delta t$ ?*

- h) Make several runs, some going in one direction and some going in the opposite direction. See if the acceleration you get for each run depends on the initial speed you give the cart and/or on the direction you give the cart.
- i) If friction and air drag were completely eliminated and the track was perfectly horizontal, all the accelerations would be zero. It is difficult to meet all of these conditions, but we do expect the value to be close to zero for all runs. See if this is so.
- j) Click on the '**Experiment**' tab at the top of the main window and select '**Delete all data runs**' to remove the timing output.

## 7. TILT AIR TRACK

- a) Raise one end of the board that the air track and gates are mounted on and place the wood supports to hold it up.
- b) Determine the angle that the board (and track) is tilted. Because the angle is rather small, using a protractor will not give a value that is accurate enough. Use a meter stick (or ruler) to measure height and either the hypotenuse or the horizontal distance; then use either the inverse sine or inverse tangent function on your calculator to determine the angle. Be sure to measure the height from the table top to the **bottom** of the board that holds the air track. Record the angle.

## 8. MAKING SEVERAL RUNS WITH TILTED AIR TRACK:

- a) Now make several runs **both up and down** the ramp. To perform a run, do the following.
1. Click on the '**Start**' button, turn the air blower on, and send the cart through both gates.
  2. Click the '**Stop**' button and turn the air blower off.
  3. Record the angle of the ramp, the direction (up or down the ramp), the time between the gates, and the two velocities in the gates in a table like that on the last page.
  4. Calculate the acceleration and record it in your table. (You do not have to record or calculate the velocity between the gates.)

If the table on the monitor gets too cluttered you can delete the displayed data by clicking on the '*Experiment*' tab at the top of the main window and selecting '*Delete all data runs*'.

- b) Examine your data and answer the following questions.
1. *Are your different values of acceleration for the same angle approximately the same?*
  2. *Does going up the track versus going down the track affect the acceleration?*
  3. *Does the velocity through the first gate affect the value of the acceleration?*
  4. *Does the time between the gates affect the value of the acceleration?*

## 9. REPEAT STEPS 7 AND 8 FOR AT LEAST TWO OTHER RAMP ANGLES.

## 10. LOOKING FOR EMPIRICAL RELATION BETWEEN ACCELERATION &amp; RAMP ANGLE:

- a) On the computer, x out the Data Studio window and then double click on the icon "AccAlongRamp" from the main menu. This will open an Excel spreadsheet.
- b) Three possible relationships for acceleration,  $a(\theta)$ , are proposed and included in a plot on the spreadsheet. Check to see that each of these three proposed relationships works for  $\theta = 0^\circ$  and  $\theta = 90^\circ$ .
- c) There is room for you to enter your experimental values for acceleration, both for up the ramp and down the ramp for several angles. Determine your best estimate (based on your runs) of the acceleration up the ramp and the best estimate of the acceleration down the ramp for each of your angles, and enter into the computer your best values (but do not include minus signs – use absolute values instead). See if your experimental values match any of the three proposed relations for  $a(\theta)$ .

**REPORT:**

1. Answer all of the questions posed in the Procedure.
2. What would the presence of friction and/or a drag force do to the acceleration along the ramp? Do you see any indication of this effect in your data? Comment.

**WORKSHEET**

Course: \_\_\_\_\_ Sec.: \_\_\_\_\_ Date: \_\_\_\_\_

Name(s): \_\_\_\_\_

Cart Shadow Length: \_\_\_\_\_ m

Distance Between Gates: \_\_\_\_\_ m

**HORIZONTAL TRACK:**

Time In Gate (s)	Time Between Gates (s)	Velocity In Gate (m/s)	Velocity Between Gates (m/s)

**Check computer calculations.**

Velocities in Gates:

First Gate:

Check? 

Second Gate:

Check? 

Velocity Between Gates using Distance Between Gates:

Check? 

Average of Velocities in Gates:

Check? **Calculate acceleration.**

$$a = \frac{\Delta v}{\Delta t} =$$

Close to zero?

