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 m/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 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 m/s^2 but less than 9.8 m/s^2. We would also expect that this acceleration would depend on the angle, θ, that we tilted the track. Can you think of different ways that the acceleration, a, might depend on the angle, θ? Remember that we do expect a = 0 m/s^2 at θ = 0° and a = 9.8 m/s^2 at θ = 90°.

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

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:
A worksheet appears on the last page for you to record your results. Your instructor may or may not have you fill it out.

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).

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. It doesn't matter which photogate is plugged into the number 1 socket. Plug the adapter into the USB link. 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 its icon on the desktop. Select '*Create Experiment*'. Then open '*Choose sensor or instrument*' window.)
    c) Choose '*Photogate timing*'.

3. CHECK PHOTOGATE ACTIVITY & MEASURE LENGTHS:
    a) When a photogate is blocked, the red LED on the photogate should light up. Test each photogate by blocking it with the cart.
    b) Now determine the length of the shadow of the cart by positioning it so that it is on the edge of blocking a photogate, and reading that edge of the cart on the air track's measuring tape.
    c) Now move the cart so that the other edge of the cart is on the edge of blocking the photogate, and read the position of the <u>first</u> edge of the cart on the air track's tape.
    d) The difference in positions of this same edge of the cart gives the length of the shadow of the cart. Calculate and record this shadow length. You will need it later.
    e) Measure and record the distance between the photogates. You will need this value later also.

4. CHECK TIMING OF PHOTOGATES:
    a) Click the '*Start*' button in the upper left of the window. The photogates are now ready to time.
    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 at least 10 seconds, and then simultaneously remove the cart and stop your watch. Check your time with the time displayed on the screen. If the detector is correctly calibrated, your time and the computer's should be close to the same.
    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 last data run*' 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*' and '*Velocity between gates*'.
    c) Click on the '*Constants*' tab. Enter the shadow length of the cart in the '*Flag*' space. Enter the distance between the gates in the '*Photogate spacing*' space.
    d) Close the '*Setup*' window.
    e) Click and drag '*Velocity in Gate (m/s)*' from the *Data* window to the *Table I* window. Click and drag '*Velocity Between Gates (m/s)*' from the *Data* window to the *Table I* window. Now the velocities of the cart through each gate and the average velocity of the cart between the gates will be displayed in addition to the times of the cart through each gate and the time the cart spends between the gates.

6. MAKE A RUN WITH HORIZONTAL TRACK & CHECK CALCULATIONS:
    a) Click the '*Start*' button.
    b) Perform a run by pushing the cart from one end of the air track, letting it go to the other end, and stopping it there. It should pass through both gates.
    c) Click the '*Stop*' button.
    d) The data should be displayed in the *Table I* window. By default, the velocities are displayed with two digits. You can increase the number of display digits by clicking on

the small down arrow on the settings icon on the table toolbar. This icon looks like a little table of rows and columns. Click on the arrow and select '*Increase precision*'.
e) Record the times in each gate, the time between the gates, the velocities in each gate, and the velocity between the gates.
f) We will now check the computer's displayed velocities and, in the process, see how it is computing them.
1. 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.
2. How can we calculate the average velocity of the cart between the first and second gate using the measured distance between the gates? Think of a way to do and see if your value agrees with the displayed velocity between the gates.
3. For a final check, calculate the average of the displayed velocities in the gates. This value should be approximately the same as the displayed velocity between the gates and the average velocity you calculated in the previous step. [If it isn't, then there is probably an error in the timing calibration of the gates, the measured shadow length, and/or the measured distance between the gates. Call your instructor over before you proceed.]
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 Δv? What value should you use for Δt?
h) If friction and air drag were completely eliminated, and the track was perfectly horizontal, the acceleration would be zero. It is difficult to meet all of these conditions, but we do expect the value to be close to zero. See if this is so.
i) Click on the '*Experiment*' tab at the top of the main window and select '*Delete last data run*' 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. Record the angle.

8. MAKING SEVERAL RUNS WITH TILTED AIR TRACK:
   a) Now make several runs <u>both</u> up and down the ramp. To perform a run, do the following.
      1. Click on the 'Start' button and send the cart through both gates.
      2. Click the '*Stop*' button.
      3. Record the time between the gates and the two velocities in the gates.
      4. Calculate and record the acceleration. (You do not have to record or calculate the velocity between the gates.)
   If the table 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 last data run*'.

b) Examine your data and answer the following questions.
   1. Are your different values of acceleration 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?
c) Record your best estimate (based on all of your runs) of the acceleration up the ramp and the best estimate of the acceleration down the ramp for this angle. (We'll consider these values again after you have experimented at several different ramp angles.)

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

10. LOOKING FOR EMPIRICAL RELATION BETWEEN ACCELERATION & RAMP ANGLE:
   a) On the computer desktop, double click on the icon "AccAlongRamp". 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 $\theta = 0°$ and $\theta = 90°$.
   c) There is also room for you to enter your experimental values for acceleration, both for up the ramp and down the ramp. Enter your values, and 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.

$a = \dfrac{\Delta v}{\Delta t} =$ Close to zero?

RAMPED TRACK: Try runs going up & down the ramp. Use at least 3 different ramp angles.

Ramp Angle (deg)	Up or Down Ramp?	Time Between Gates (s)	Velocity In Gate 1 (m/s)	Velocity In Gate 2 (m/s)	Acceleration (m/s^2)