PHYS 1401 – General Physics I
Laboratory # 3
Velocity and Acceleration

INTRODUCTION

In this exercise, we will be getting familiar with the concepts of displacement, velocity, and acceleration. using the frictionless air tracks. You will be using "air tracks," which create a cushion of air so that small "carts" can slide along the track without friction. Before we begin the formal experiment, I want you to make some predictions about what will happen. Use your imaginations and discuss as a group the answers to the following questions. Write the answers on a separate sheet of paper, along with the names of everyone in your group, and turn them in *before* you start gathering any data.

Predictions for Lab 3

Prediction 1: If the air track is perfectly level, what do you think will happen to the velocity of the cart as it slides along the track? Will it increase, decrease, or stay the same? Justify your answer.

Prediction 2: If the air track is slightly tilted, what do you think will happen to the velocity of the cart as it slides down the track? Justify your answer.

Prediction 3: If the mass of the cart is increased, how will the velocity at the bottom of the track for this more massive cart compare to the velocity at the bottom of the track for the lighter cart in the previous prediction? Justify your answer.

Prediction 4: If the mass of the cart is restored to its original value, but the incline is increased, how will the velocity of the cart at the bottom of this more inclined track compare to the velocity of the cart at the bottom of the track for the lesser incline? Justify your answer.

Part 1: Level Airtrack

First we will explore the motion of an object on an "air track." Air flowing through the air track creates a nearly-frictionless surface for us to slide the "cart" along. The "photogates" will allow the computer to record the velocity of the cart as it passes through each photogate. Notice how the cart has a long "flag" on top of it. The electric eye in each photogate registers when the flag enters and exits the gate. Since the computer knows the distance from one end of the flag to the other, it can divide that distance by the time it takes the flag to get through the gate and turn that into a velocity. The velocity represents the average velocity of the cart as it passes through the gate.

For this part, the air track should be flat on the table. First determine which of the gates is #1 and which is #2. Place the photogates at the 50 centimeter and 150 centimeter points of the air track, and make sure that the flag trips each gate (a red light will light up on the gate when the flag passes through it). Now hit the “Collect” button on the computer and slide the cart under one gate. Look at the screen to see if the data from that gate registers as 1 or 2. Label the bases of the gates with yellow notes to make sure that you can keep them straight.

Give the cart a gentle push so that it will pass under both gates. Stop it before it reaches the other end of the air track.

Question 1: How does the velocity of the cart change between the two gates? Does this agree with the prediction you made?

Now give the cart a slightly harder push.

Question 2: How were the velocities different from the gentler push? In this case, how does the velocity of the cart change between the two gates?

Part 2: An Inclined Surface

Place the smaller 200-gram cylindrical weight underneath the single foot of the air track so that one end of it is raised up. Place the photogates at the 20 cm (gate #1) and 120 cm (gate #2) points on the air track. Make sure the gates are at the proper heights for the flag to trip the electric eye – you may have to use books to prop them up. Always make sure that you know which gate is #1 and which is #2! Take the cart up to the very top of the track and hold it motionless there. Click the “Collect” button and let the cart slide down the track. It is very important that you ***not*** give the cart a push this time! Catch the cart before it can reach the bottom of the incline!

The data you see on the screen should look something like this:

Time	Velocity1	Velocity2
Number (t_1)	Number (v_1)	
Number you won’t use		
Number (t_2)		Number (v_2)
Number you won’t use		

So now you have four pieces of data: the speed of the cart as it passes through gate #1 (call it v_1), the time the car passes through gate #1 (call it t_1), the speed of the cart as it passes through gate #2 (call it v_2), and the time the car passes through gate #2 (call it t_2). You can use these data to calculate the acceleration of the cart between gate #1 and gate #2, using the definition of acceleration as the change in velocity divided by the change in time.

Now place the gates at 30 cm and 130 cm. As before, record the velocities and times at each gate. Repeat this, moving the gates 10 cm each time, until you take your final pair of readings when the gates are at 70 cm and 170 cm. Make sure the gates are always 1 meter apart. Record your velocity and time data in a table, along with the acceleration you calculate each time. You **MUST** start the cart from the top of the track ***every time*** and let it slide without a push!

Question 3: How does the velocity of the cart change as it slides down the track? Does this agree with the prediction you made?

Question 4: What force is causing the cart to slide down the incline? As the cart slides down, does the acceleration produced by the force increase, decrease, or stay the same? Back up your statement with data.

Part 3: A More Massive Cart

Place the small silver weights on either side of the cart to add more mass. Repeat all of your velocity measurements and acceleration calculations from Part 3 with this more massive cart. Record your findings in two data tables as before.

Question 5: Did your findings confirm your prediction for greater mass? How does mass affect the speed of an object sliding down an incline? How is the acceleration affected?

Part 4: A Greater Incline

Remove the silver weights from the cart and place the larger 500-gram cylindrical weight under the foot (instead of the shorter cylinder) to raise the air track up even more. Repeat your measurements of velocity and calculations of acceleration from Part 3 for this greater incline. Record your findings in two data tables.

Question 6: Did your findings confirm your prediction for greater inclination? How does the height of the incline affect the speed of an object sliding down an incline? How is the acceleration affected?

Part 5: Free Fall

In this part of the lab exercise we will be measuring a very commonly used acceleration, the acceleration caused by gravity. We will measure this acceleration by observing objects that are only being influenced by the force of gravity. We say that these objects are in “free fall.” Now in reality, air resistance is affecting any falling object as well as gravity, but the effect should be small, so long as we choose reasonably aerodynamic objects such as spheres.

We will measure the acceleration due to gravity by dropping objects from set distances and timing how long it takes for them to fall. Recall that we have an equation relating distance and time for an accelerating object:

$$\mathbf{x_f = x_0 + v_0 t + (1/2)at^2} \quad \text{where}$$

x_f = the final position of the object
x_0 = the initial position of the object
v_0 = the initial velocity of the object
t = amount of time that object accelerates
a = acceleration of object

In this case, we will be dropping an object, so the acceleration will be the acceleration due to gravity. The factors v_0 and x_f will be constant for all experiments – what will their values be? The time t is what we will be measuring, and the acceleration due to gravity is what we are trying to find. That leaves only one thing that we can vary: the starting position.

We will vary the initial position by dropping the ball from different heights. First, hold the ball 20 centimeters above the timer. Drop the ball onto the timer and record the result. Do this 5 times and find the average time required to fall from 20 centimeters. Repeat this for heights of 5 cm, 10 cm, 30 cm, 40 cm, 60 cm, and 80 cm.

Make a graph with average time on the x-axis and distance fallen on the y-axis. "Connect the dots" to get an idea of how time changes with distance. Do *not* try to "fit a line." Just connect the data points!

Question 7: The graph of distance vs. time should not look like a straight line. What shape graph does it look like? Rewrite the equation on the first page with the appropriate vales for v_0 and x_f plugged in. Remember that the distance fallen is x_f – x_0. Does this equation make sense when compared to your graph?

Plug the time values and distance values into the equation from Question 7 and calculate a value for the acceleration due to gravity for each height. For each drop, calculate the final velocity, the velocity when the ball hits the timer. Use the formula

$$\mathbf{v_f = v_o + at}$$

Put together a data table with one row for each observation and four columns: height, time, acceleration, final velocity.

Question 8: How does the acceleration due to gravity vary with the distance fallen? What is the relationship between distance fallen and final velocity? Explain in words, in terms of acceleration, why this is so.

Repeat the observations above for a more massive object. Create a data table and graph for this falling object identical to those for the less massive ball.

Question 9: How does the acceleration due to gravity vary with the mass of the falling object? How does final velocity vary with the mass of the falling object?

Question 10: If air resistance were an important factor for the spheres, how would the acceleration of the falling spheres compare to the ideal value for the acceleration due to gravity? Compare your average calculated value for the acceleration of the spheres to the expected value of g (9.8 m/s^2) using the percentage difference formula, and assess how important air resistance is in our lab. Remember to pay attention to significant figures!

$$percentage\ difference = \frac{expected\ value - calculated\ value}{expected\ value}\ x\ 100$$