Name: ______________________

Partner(s): ______________________

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Date: ______________________

One Dimensional Motion

1. Purpose:

This lab has a dual purpose. We want you to become familiar with the operation of a linear air track and recognize this as another instance of the cultural preference that physicists have towards simplicity and minimalism. You will then use it to investigate the motion of a body subjected to a constant force and discover the functional relationship between distance, velocity, and time.

2. Background:

- Required for this lab:

a) A good understanding of the lab reading material provided here.
b) Science Workshop – Data Studio program
c) KaleidaGraph or Graphical Analysis. So familiarize yourself with KaleidaGraph or Graphical Analysis by reading the information available in the lab manual reading material for "Introduction to Our Curve Fitting Computer Programs"

Prior reading and preparing for your experiment well ahead will save you a great deal of time and frustration in the lab.

"Kinematics" is the study of motion, as opposed to "dynamics", where one attempts to understand the "cause" of motion. In this experiment you will analyze one-dimensional motion and determine the equation of motion, expressed in the form:

$$x_t = f(t) \qquad (1)$$

where $\boldsymbol{x_t}$ is the location of the object at time $\boldsymbol{t}$.

To study the one-dimensional motion, you will use a cart and an air track. An air track is a *nearly* frictionless device, which can be used to study motion under ideal conditions. Carefully inspect all parts of the air track and note their function. While nothing is breakable during ordinary use, it *is* a delicate instrument and should be treated as such. In particular, **don't drop the carts!** If a cart is dropped, contact your instructor and ask them to inspect it carefully. With the blower on, inspect all the air holes to ensure that they are open.

In practice, we can never (or can we?) achieve a perfectly frictionless environment; even a levitated cart set in motion will eventually come to rest. Thus, you should investigate how good an approximation it is to consider the air track frictionless.

The simplest example of motion is an object moving at constant velocity, v_o, in a straight line. In this case, the change in an objects position after a period of time, t, is trivial.

$$\Delta x = v_o t \tag{2}$$

When the object is accelerating (*i.e.* the air track is inclined, there is substantial friction, there is a big draft of air, *etc.*) this relationship will be more complex. If the acceleration ***a*** is uniform (*i.e.* does not vary over the time of the experiment), then the change in an objects position is:

$$\Delta x = v_o t + \tfrac{1}{2} a t^2 \tag{3}$$

where v_o is the initial velocity of the object at the beginning of the interval $\boldsymbol{t}$ and $\boldsymbol{a}$ is the uniform acceleration that the object is subject to. Because the acceleration is constant, the velocity, v_f, of the object at time, t, satisfies:

$$v_f = v_o + at \tag{4}$$

$$v_f^2 = v_o^2 + 2a\Delta x \tag{5}$$

where Equation (5) is derived by squaring Equation (4) and substituting in Equation (2).

If the acceleration, ***a,*** is itself changing with time, the equations of motion are more complex. You will study the motion of the cart down the inclined air-track for which equations (3) and (5) will (probably) provide a reasonably good description.

3. *Procedure:*

The setup is depicted in Figure 1. The air track will be elevated at one end. Data will be taken using the Science Workshop™ software and two photogates, interpreted with the sensor "Photogates (2)."

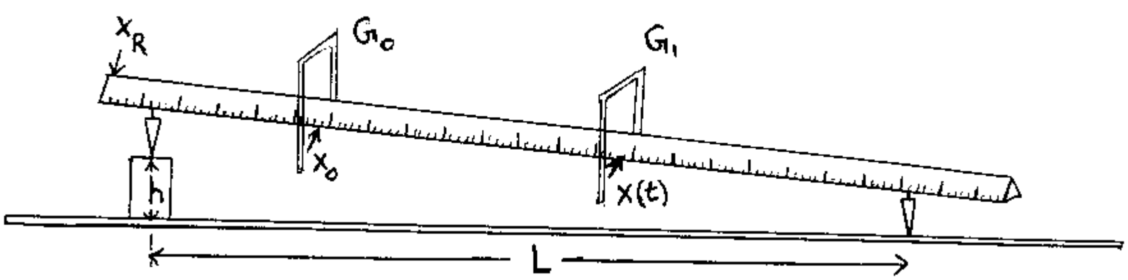

Figure 1

In the first part of this lab, you will measure the duration of time, ***t,*** that it takes for the air cart to travel a distance $\boldsymbol{\Delta x = x(t) - x_o}$ on the air track. The distance $\boldsymbol{\Delta x}$ is the distance that the cart travels between the two photogates. You will repeat this six times for six different distances, $\boldsymbol{\Delta x}$.

If the initial velocity, v_o, and the acceleration remain the same during each run, then you should have the form of Equation (3). The acceleration will be constant if the angle of inclination, θ, remains constant and any frictional forces do not depend on the location or speed of the cart. Additionally, if you start the cart *from rest* at the same point on the air track and the position of the first photogate remains fixed during each measurement, the initial velocity will remain constant. Different distances Δx can be obtained by varying the location of the second photogate.

By inspection, you might expect that the acceleration, ***a*,** depends upon the angle of inclination, θ, of the air track.

- In the space below, draw a force-body diagram of the cart and apply **Newton's 2nd Law** (which is in your text) to *find* the acceleration of the cart in the direction of motion.

You should find that the acceleration is given by Equation (6):

$$a = g \sin\theta \qquad (6)$$

- Keeping θ fixed is easy: place a block of fixed height ***h*** under the single-foot end of the air-track. The first photogate must be kept stationary, approximately 20 cm from the high end of the track.

- You should measure seven reasonably spaced data points covering the entire length of the air track.

- For each distance Δx in Table 1, find the time ***t*** by averaging over six trials.

4. Data:

Determine the angle of inclination:

m_{cart} = ____________

h = ____________

L = ____________

$\theta = \tan^{-1}(h/L)$ = ____________

- Consult the drawing on the previous page to make sure that you measure the proper h and L.

Measuring the Time of Travel for Various Distances:

[Photogates (2); Table: Time between Gates 1 & 2]

Trial	x_o (Initial Gate)	$x(t)$ (Final Gate)	t (Time)	$\Delta x = x(t)$ (Displacement)
1				
2				
3				
4				
5				
6				
7				

5. *Analysis:*

Part 1:

- Enter your data, **Δx** and ***t*,** into a graphing program. From the previous discussion, we know that the relationship should be modeled by Equation (3), so we expect that your plot of Δx and t should appear to resemble a polynomial of second order, as seen in Equation (7).

$$y(x) = a_0 + a_1 x + a_2 x^2 \tag{7}$$

  Here, y and x refer to the y-axis and the x-axis, not physical quantities, and a_0, a_1, a_2 represent the adjustable coefficients of the polynomial. They are adjusted by your curve–fitting software in order to make the fitting curve best approximate your data. It is up to you to decide whether the resulting polynomial is a physically reasonable (or "meaningful") fit to your experimental data.

- Perform the fit and record the "best-fit values" for the coefficients below.

a_0 = ___________

a_1 = ___________

a_2 = ___________

- Attach a copy of your data and the fitted line.

A comparison of equations (3) and (7) tell us that a_0 should be 0, a_1 should be v_o and a_2 should be $\frac{g \sin\theta}{2}$. You have already computed the *theoretical* value of ***a*** using Equation (6). A theoretical value of v_o can be computed by using Equation (3). Complete the table below.

	Experimental	Theoretical	% Error
acceleration, a ( )			
initial velocity, v_o ( )			

- ❖ Does your fitted value of a_o agree with what you expect? Comment.

- ❖ Does your fitted value of a_1 agree with what you expect? Comment.

- ❖ Does your fitted value of a_2 agree with what you expect? Comment.

Part II:

We can also study kinematics by measuring the initial, v_o, and final velocities, v_f. When you measured the time that the cart spent between the photogates, the software also measured the time required for the cart to pass through each photogate, Δt. If the length, ΔL**,** of what passed through the photogate is sufficiently small, the quantity ΔL / Δt provides a good approximation to the instantaneous velocity of the cart as it passes through the photogate.

The choice of the length, ΔL, is a compromise between two conflicting needs. If ΔL is too small, then the transit time, Δt, is too small and the percentage error in determining *v(t)* is unacceptably large. On the other hand, if ΔL is too large, the measured speed is not a good approximation to the instantaneous speed. Be careful in determining your value of ΔL.

Explain your method in the space below.

If you were careful when taking your data earlier, you do not need to make any additional measurements. (Aside: reading the lab write-up ahead of time does save you time in lab). The table below will guide you through the measurements to calculate the acceleration using Equation 4.

ΔL = ___________

Δ (Displacement)	Δ_{1} ( ) (Time Gate 1)	Δ_{2} ( ) (Time Gate 2)	v_1 ( ) (Velocity Gate 1)	v_2 ( ) (Velocity Gate 2)	a_{cal} ( ) (Acceleration)

a_{average} = ___________

6. Questions:

i. What is the magnitude of the force exerted on the air cart by the air from one of the holes in the air track (i.e., the force lifting the cart up)?

ii. Is the assumption that the air track is frictionless valid? Support your answer using the data you took in this lab.

7. Initiative:

Possible ideas:

- Design an experiment to determine the extent of frictional effects on the air track. Do this experiment and present your data and analysis.

8. Conclusions: