Experiment

1

1D Motion-The Acceleration of a Cart

Introduction

The quantitative investigation of motion for real life situations is always complicated by external influences such as friction and the necessity of making measurements (interacting with the system). Ideal theoretical models, which are so useful for discussion purposes, cannot generally be duplicated in the laboratory. In this first laboratory exercise, you will look at an example of one-dimensional accelerated motion. You will soon realize that a careful consideration of external influences along with good experimental technique is essential to an experiment's outcome. It is highly recommended that you fully understand a procedure before attempting it, and that you always pay close attention to detail.

Objectives

Experimental

1. To graphically describe the motion of an accelerated object in one dimension.
2. To understand error analysis.
3. To understand the difference between systematic, random, and personal errors.

Learning

1. To practice making measurements and working with significant figures.
2. To review and practice the techniques of graphing.
3. To reinforce your understanding of one-dimensional kinematics.

Theory

Before beginning, be sure that you understand the basic concepts of position, displacement, velocity and acceleration in one dimension, and how they relate to each other. You should also review the expression for motion at constant acceleration (refer to derivation in your textbook).

1. Define the terms displacement, position, velocity, and acceleration using complete sentences (2 points).

2. Prove that the average velocity in a time interval from t_1 to $t_2=t_1+\Delta t$ is equal to the instantaneous velocity in the middle of the time interval between t_1 and t_2 {*e.g.* $(t_1+ t_2)/2$} for an object moving at constant acceleration (2 points).

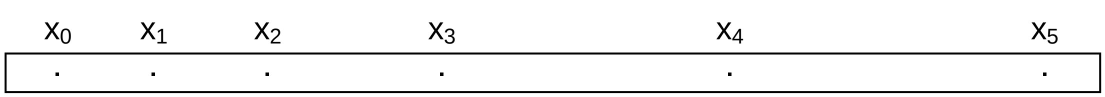
3. Starting with the expressions for average acceleration (refer to your textbook), average velocity at constant acceleration; algebraically (NO CALCULUS) derive the equation for one-dimensional motion that relates displacement to the acceleration, assuming acceleration is constant (2 points).

Δy = ______________________________________

Procedure

1. Locate the experimental setup and check to see that it is set up correctly, but do not plug in the synchronous spark timer transformer.
2. Secure the cart at the release position using the loop of string.
3. Thread a suitable length of heat sensitive tape down the spark gap channel and through the spark gap, and attach the leading end to the top of the cart with a small piece of masking tape. It does not matter which side of the tape is up. Be sure to position the timer to minimize tape friction as it is being pulled through the spark gap, check to see that the line of motion of the cart is parallel to the spark gap channel.
4. Pull the cart back against the timer using the heat sensitive tape and, holding it in place with the tape, remove the loop of string that was securing the cart.
5. Push the red button that turns on the spark, and very quickly let go of the heat sensitive tape (thus releasing the cart). Be sure to unplug the transformer before proceeding. (CAUTION: The transformer outputs approximately 5000 volts of electric potential, so stay clear of the exposed leads while it is plugged in.)
6. Disconnect the strip of heat sensitive tape and inspect the pattern of heat marks. If you are not satisfied, repeat steps 2 through 5.
7. From your strip of tape, measure and record position data in the table provided (see "Analysis"). The tape should look similar to the picture below.

Data & Analysis:



Using the above representation of your data tape as a reference and the formulas below, the concepts you proved in Theory section, complete Table 1 and Table 2. Notice that column entries are staggered. This is to make it easier to see which two values to the left of an entry were used to calculate that entry. For example, Δx_1 was calculated from x_1 and x_0. Also notice that the values of both v_{avg} and a are average values for their respective intervals.

Displacement:	$\Delta x_1 = x_1 - x_0$, $\Delta x_2 = x_2 - x_1$, etc.
Average Velocity:	$v_{avg1} = \Delta x_1 / \Delta t$, $v_{avg2} = \Delta x_2 / \Delta t$, etc.
Change in Velocity:	$\Delta v_1 = v_2 - v_1$, etc.
Acceleration:	$a_1 = \Delta v_1 / \Delta t$, $a_2 = \Delta v_2 / \Delta t$, etc.
Instantaneous V	$V_1 = V_{avg1}$ at $t_1 + \Delta t/2$, $V_2 = V_{avg2}$ at $t_2 + \Delta t/2$ (Table 2)

Table 1: Position & Time Data

t (s)	x (cm)	Δx (cm)	V_{avg} (cm/s)

Table 2: Velocity & Time Data

t (s)	V (cm/s)	ΔV (cm/s)	a(cm/s^2)

Graphical Presentation of Data: You are to construct the following two graphs that are to be attached to this report (Remember to follow the "Rules of Graphing"):

1. Position vs. Time
2. Instantaneous Velocity vs. Time

1. Perform a "fit" to your data for the position vs time graph and determine the object's acceleration along with the uncertainty in its value, and the object's initial velocity along with the uncertainty in its value. Record these values in Table 3. You should only keep one significant figure for the uncertainty (standard deviation) in the cart's acceleration**. How many significant figures should you report for your value?** _Paste your graph below._

2. "Fit" your data in the instantaneous velocity vs time graph and determine the acceleration along with the uncertainty in its value, and initial velocity from the fit parameters. Record these values in Table 3. You should only keep one significant figure for the uncertainty (standard deviation) in the cart's acceleration. **How many significant figures should you report for your value?** _Paste your graph below._

3. From the acceleration data in Table 2, calculate the average acceleration, its standard deviation (s), and the precision of the mean $\sigma = \frac{s}{\sqrt{N}}$. You can use Excel for this. Record these values in Table 3.

Results

Report the extracted values of the cart's acceleration in the table below.

Table 3

	Initial Velocity (m/s)	Uncertainty (m/s)	a (m/s^2)	Uncertainty (m/s^2)
Quadratic Fit (x vs. t plot)				
Linear Fit (v vs. t plot)				
Average from Table 2				$\frac{s}{\sqrt{N}} =$

Conclusion

1. Does the velocity vs. time graph, indicate that the acceleration of the cart is constant? Explain?

2. Why is your measured initial velocity not equal to zero?

3. State which of the values in the third column in Table 3 is most reliable. Explain.

4. What is the purpose of comparing the value of a measured physical quantity to a value we trust?

5. List and explain the random and systematic errors in your experiment. How can you determine the dominant source of error (random or systematic) in your experiment?