**Experiment**

**2**

1D Motion

|  |
| --- |
|  |

**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, generally cannot be duplicated in the laboratory. In this laboratory exercise, you will look at an example of one-dimensional accelerated motion down an inclined plane. You will soon realize that a careful consideration of external influences along with good experimental technique is essential to the outcome of an experiment. It is highly recommended that you fully understand the 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 calculate the acceleration due to gravity from measured quantities.
      3. To understand error analysis.
      4. To understand the difference between systematic, random, and personal errors.

**Learning**

To practice making measurements and working with significant figures.

To review and practice the techniques of graphing

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 freefall, and how the displacement mathematically depends on the acceleration due to gravity (refer to derivation in your textbook).

1. Define the terms displacement, position, velocity, and acceleration using complete sentences.

Displacement is equal to change in position over change in time. An example might be if someone were to run to the store then return with groceries, her displacement would be zero because she did not change her position after returning. Velocity is equal to the magnitude and direction in a given reference point. An example might be someone the woman running to the store and returning home. On her way home, her velocity is decreasing despite her speed being constant throughout the drive home. Acceleration is change in position over change in time. Using the example from the velocity example, the woman is decelerating as she returns to her origin point despite her speed remaining constant.

2. Prove that the average velocity in a time interval from t1 to t2=t1+t is equal to the instantaneous velocity in the middle of the time interval between t1 and t2 {*e.g.* (t1+ t2)/2} for an object moving at constant acceleration.

Average velocity

This will put the give you the point at the exact middle of the two velocities.

If you take the derivative at the same point in time, you will see we get the same slope. Or, if you take the limit you will see the same slope.

At t equals the same point, the change in slope over the change in time will be equal to the average velocity.

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 constant acceleration and time.

**Δx** = \_\_\_\_\_\_\_\_\_\_\_\_174\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Procedure

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Fig 1: Photo of experimental set-up.

1. Locate the experimental setup and check to see that it is set up correctly.
2. Measure and record the angle the incline makes with the horizontal.
3. Cut a piece of paper tape as long as the distance between the timer and the end of the incline.
4. Attach the paper tape to the cart.
5. Thread the other end of the paper tape through the tape timer with the cart at the top of the incline.
6. Set the Timer to 40Hz and turn it on.
7. Release the cart being careful to allow the tape to thread smoothly through the timer.
8. Tape the paper tape to a table and measure the position of the dots. Don’t use the first dot because the mass may not have begun to move when the dot was made. Record the data in Table 1.

Note: Only one strip of tape is needed for each group. The tape is costly and inconvenient to purchase, so please do not waste it.

**Data & Analysis:**

x0 x1 x2 x3 x4 x5

. . . . . .

Fig 2: schematic of data tape with location marks

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, Δx1 was calculated from x1 and x0. Also notice that the values of both vavg and a are average values for their respective intervals.

Displacement: Δx1 = x1 - x0 , Δx2 = x2 - x1 , etc.

Average Velocity: vavg1 = Δx1 /Δt , vavg2 = Δx2 /Δt , etc.

Change in Velocity: Δv1 = v2 - v1 , etc.

Acceleration: a1 = Δv1 /Δt , a2 = Δv2 /Δt , etc.

Instantaneous V V1=Vavg1 at t1 +t/2, V2=Vavg2 at t2 +t/2 (Table 2)

# θ = \_8.8\_\_\_\_.2\_\_

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# Table 1: Position & Time Data

**VELOCITY EXCEL TABLE ATTACHED AND LABELLED.**

|  |  |  |  |
| --- | --- | --- | --- |
| T |  |  |  |
| 0 | 0.8 | 0.7 | 26 |
| 0.025 | 1.46 | 0.8 | 32 |
| 0.05 | 2.44 | 1.0 | 39 |
| 0.075 | 3.5 | 1.1 | 42 |
| 0.1 | 4.61 | 1.1 | 44 |
| 0.125 | 5.8 | 1.2 | 48 |
| 0.15 | 7.09 | 1.3 | 52 |
| 0.175 | 8.09 | 1.0 | 40 |
| 0.2 | 9.79 | 1.7 | 68 |
| 0.225 | 11.5 | 1.7 | 68 |
| 0.25 | 12.79 | 1.3 | 52 |
| 0.275 | 14.39 | 1.6 | 64 |
| 0.3 | 16.08 | 1.7 | 68 |
| 0.325 | 17.8 | 1.7 | 69 |
| 0.35 | 19.59 | 1.8 | 72 |
| 0.375 | 21.41 | 1.8 | 73 |
| 0.4 | 23.32 | 1.9 | 76 |
| 0.425 | 25.31 | 2.0 | 80 |
| 0.45 | 27.39 | 2.1 | 83 |
| 0.475 | 29.49 | 2.1 | 84 |
| 0.5 | 31.6 | 2.1 | 84 |
| 0.525 | 33.8 | 2.2 | 88 |
| 0.55 | 36.1 | 2.3 | 92 |
| 0.575 | 38.41 | 2.3 | 92 |
| 0.6 | 40.85 | 2.4 | 98 |
| 0.625 | 43.77 | 2.9 | 117 |
| 0.65 | 45.79 | 2.0 | 81 |
| 0.675 | 48.35 | 2.6 | 102 |
| 0.7 | 51.01 | 2.7 | 106 |
| 0.725 | 53.74 | 2.7 | 109 |
| 0.75 | 56.55 | 2.8 | 112 |
| 0.775 | 59.4 | 2.9 | 114 |
| 0.8 | 62.29 | 2.9 | 116 |
| 0.825 | 65.3 | 3.0 | 120 |
| 0.85 | 68.55 | 3.3 | 130 |
| 0.875 | 71.58 | 3.0 | 121 |
| 0.9 | 74.56 | 3.0 | 119 |
| 0.925 | 77.91 | 3.3 | 134 |
| 0.95 | 81.25 | 3.3 | 134 |
|  | 0.8 | 0.7 | 26 |

# Table 2: Velocity & Time Data

|  |  |  |  |
| --- | --- | --- | --- |
| T | V |  | A |
| 0 | 26.4 | 6 | 0 |
| 0.025 | 32.4 | 6 | 240 |
| 0.05 | 39.2 | 7 | 272 |
| 0.075 | 42.4 | 3 | 128 |
| 0.1 | 44.4 | 2 | 80 |
| 0.125 | 47.6 | 3 | 128 |
| 0.15 | 51.6 | 4 | 160 |
| 0.175 | 40 | -12 | -464 |
| 0.2 | 68 | 28 | 1120 |
| 0.225 | 68.4 | 0 | 16 |
| 0.25 | 51.6 | -17 | -672 |
| 0.275 | 64 | 12 | 496 |
| 0.3 | 67.6 | 4 | 144 |
| 0.325 | 68.8 | 1 | 48 |
| 0.35 | 71.6 | 3 | 112 |
| 0.375 | 72.8 | 1 | 48 |
| 0.4 | 76.4 | 4 | 144 |
| 0.425 | 79.6 | 3 | 128 |
| 0.45 | 83.2 | 4 | 144 |
| 0.475 | 84 | 1 | 32 |
| 0.5 | 84.4 | 0 | 16 |
| 0.525 | 88 | 4 | 144 |
| 0.55 | 92 | 4 | 160 |
| 0.575 | 92.4 | 0 | 16 |
| 0.6 | 97.6 | 5 | 208 |
| 0.625 | 116.8 | 19 | 768 |
| 0.65 | 80.8 | -36 | -1440 |
| 0.675 | 102.4 | 22 | 864 |
| 0.7 | 106.4 | 4 | 160 |
| 0.725 | 109.2 | 3 | 112 |
| 0.75 | 112.4 | 3 | 128 |
| 0.775 | 114 | 2 | 64 |
| 0.8 | 115.6 | 2 | 64 |
| 0.825 | 120.4 | 5 | 192 |
| 0.85 | 130 | 10 | 384 |
| 0.875 | 121.2 | -9 | -352 |
| 0.9 | 119.2 | -2 | -80 |
| 0.925 | 134 | 15 | 592 |
| 0.95 | 133.6 | 0 | -16 |
| 0 | 26.4 | 6 | 0 |

**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
3. 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. **How many significant figures should you report for your value of the acceleration and the initial velocity?** *Paste your graph below.*

Chart, line chart

Description automatically generated

1. “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. **How many significant figures should you report for your value of the acceleration and the initial velocity?** *Paste your graph below.*

Chart, line chart

Description automatically generated

1. From the acceleration data in Table 2, calculate the average acceleration, its standard deviation (s), and the precision of the mean. Record these values in Table 3.

**Average Acceleration Calculations**:

x109.9487

**Standard Deviation Acceleration Calculations**:

Text, letter

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**Precison of the mean**

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1. Free body analysis of the set up predicts that the acceleration is related to gravitational acceleration by:

,

Where, g is the acceleration due to gravity and θ, is the angle the incline makes with the horizontal.

## Results

Report the extracted values of g (one from each graph) in the table below and calculate the percentage of the error (gRocklin = 9.8006 m/s2). Show your work for the percent error calculation below.

**Data Explained**

For the quadratic fit, we found A = 50.8 cm, which If you consider the the quadratic equation for position, , we find that acceleration Is being halved. Multiplying that by two, we find the acceleration to be approximately 100 cm per second squared. Then using the equation we can divide a by sin theta to get g.

Initial velocity is obtained through the use of SciDavis, finding the first velocity dot or in the position case by finding the y intercept.

**Table 3: Results for Initial Velocity and Acceleration**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Initial Velocity (m/s)** | **Uncertainty (m/s)** | **a (m/s2)** | **Uncertainty**  **(m/s2)** |
| Quadratic Fit (x vs. t plot) | .0368 | .0004 | .0508 | .0005 |
| Linear Fit  (v vs. t plot) | .033 | .002 | .104 | .006 |
| Average from Table 2 |  |  | .1 | .6 |

### Conclusion

* + - 1. Does the velocity vs. time graph, indicate that the acceleration of the falling mass is constant? Explain?
         1. The graphs indicate that the acceleration of the falling mass is constant. Because the acceleration is equal to g \* sin (theta), there should be no increase or decrease in acceleration. That is a static number.
      2. Why is your measured initial velocity not equal to zero?
         1. During the experiment, we decided to discard the intital values of the car remaining at rest. The first value we see is the change in position from the resting location to the location reached after .025 seconds.
      3. State which of the values in the third column in Table 3 is most reliable. Explain.
         1. I would argue that the uncertainty from the average is the most reliable. Because it allows for a larger range of potential values, we find that the accuracy of the uncertainty is increased.
      4. Use error propagation to determine the uncertainty in your calculation of g for each case. Do the values agree with each other, and do they agree with the accepted value?
         1. The values we found for gravity were only slightly off the expected value of gravity. In our case we found

**Percent Error Calculations**

* + - 1. What is the purpose of comparing the value of a measured physical quantity to a value we trust?
         1. We are practicing the scientific method, becoming more familiar with our instruments, and creating conclusions of our own to draw on for future experiments. We are learning to conduct experimental data gathering in a whole new way. Each time we complete a lab we become more adept, more precise, and more better suited for our future as stem graduates.
      2. 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?
         1. The most systematic error that was present throughout the lab was friction. Our group had to restart the experiment from scratch due to the friction that was present within the time instrument. As the tape passed through the device that would mark a dot for every .025 seconds, the tape making contact with the time instrument caused our car to jolt forward. This created mistakes in our data tables that were simply too much to recover from. We had to restart the experiment. I’m not sure if these errors could be avoided. I approached our Professor and voiced my concerns about the integrity of the experiment, and I was told these issues are prevalent throughout any device that can be purchased to accomplish this task. These inconsistencies were unavoidable.