Introduction
Experimentation is fundamental to physics (and all science, for that matter) because it allows us to prove or disprove our hypotheses about how the physical world works. Though you won’t likely be discovering any new laws of physics in this class, lab activities do allow you to actually see how the concepts you study work. Sometimes, however, the true meaning of what is happening in an experiment isn’t readily apparent – it’s the data that make things clear. Graphing is one of the most effective ways to interpret and display data, and you will use this valuable tool throughout the course.

In the first part of this lab, you will set up an experiment and collect data (it’s not as simple as you might think!). Later, you will explore what your data means by graphing it.

When finished with this lab you should be able to:
- Describe how the choice of coordinate system affects the values of x, t, Δx, & Δt.
- Derive values for Δx, Δt, & v from tables of x and t values.
- Demonstrate that you can correctly read x, t, Δx, Δt and v from an x vs. t graph.
- Describe (in words) the motion of an object given its x vs. t graph. Include information about position, displacement, times, and speed.

Purpose: (Write in your lab notebook)
What is the Relationship between ___________ and ____________ for the situation of…

Theory: (Write in your lab notebook)
Sketch your expected x vs t graph shape.
Explain the expected motion in words. You may also include sample numbers if it helps.
Find a 1 sentence quote from the text, copy it and give the page number.

Procedure: (Summarize steps and diagram in your lab notebook)
You will need the following materials to complete this activity:

- 3 Stop Watches
- 1 Length Of Track (Al Channel)
- Small Piece of Clay
- 1 Steel Ball Bearing
- 1 Meter Stick
- Starting Ramp

1. Set the aluminium channel (track) on the lab bench, and place the starting ramp on one end of the track. (This ramp gives the ball a starting speed that is repeatable.)

2. Mark the ramp with a “starting point”, as you will need to release the ball from the same position for each “run”.

3. Set the meterstick along the track so that the 0 meter position corresponds to the location where the ball first hits the track. Mark this, as well, three more positions along the track at equal intervals. Use the metric side of the meterstick. Record the positions.
4. Station an observer with a stopwatch at each position (except the 0 meter position). Roll the ball. Each observer should stop their watch when the ball crosses their position. Record the times. Roll three times recorded all times. Label these as Run 1.

5. Repeat Steps 3 and 4 with the same speed and the meterstick adjusted so that its 20 cm mark is at the bottom of the starting ramp. Label this data Run 2.

6. Repeat Steps 3 and 4 with a different speed and the meterstick set as in Run 1. Label this as Run 3.

Make sure that you obtain position vs. time data for the ball rolling along the track at a uniform rate, not speeding up and not slowing down. (It is best not to roll the ball too slowly or too quickly.)

![Figure 1 – Setting up the Experiment (Run 1)](image)

**Group Discussion Questions:** Make sure that you know how to add this information to the procedure steps.

Each stopwatch will be stopped as the ball passes that watch's assigned position. However, you'll need to determine how the watches will be started. Explain when you intend to start each watch.

Why is repeatability desirable in a lab situation such as this where the ball is rolled down the hill? What is it that is repeatable?

**Collecting Data**

**Uncertainty:** *(Show a bar-chart/number-line in your lab notebook with your work to find the uncertainty.)*

Before taking down your equipment, you will need to do a mini-experiment to find the value of the uncertainty for position and time for this lab.

Time: You will need to take several measurements of time. Roll the ball the same way many times and find the time that it passes one of the positions on your track. Make sure that you have more than 10 values. Why 10? Remember that generally, you must keep...
90% or more of your values. Then use the technique from Lab 0 to determine an uncertainty for time.

Position: You will need to take several measurements of position. One possibility is to establish a random location with a mark on the track. Then have all members of the team record the position. Use these values to find an uncertainty for position. What is your uncertainty for position? How did you decide on your range value?

**Working Data Tables**

Sample Table for Run 1. Create similar ones for Runs 2 and 3. Copy all three into your lab notebook.

<table>
<thead>
<tr>
<th>Run 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position (cm) +/-</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Formal Data Table:** *(Write in your lab notebook)*

The position and time data was the result of direct measurement. We call this “measured data”. Even though the average time was not directly measured, it is a “best value” description of the time for each position. For this reason, the average value is usually listed in your final data table as measured data. The uncertainty should also be given. You may state the uncertainty anyway that you consider clear. One method is to list it as part of the column heading.

Create a formal data table that contains only the average values for each run (and units and uncertainty).

**Analysis:**

**Group Discussion Questions:** Make sure that you know how to do these calculations if asked.

Explain how to calculate the displacement between Positions 2 and 3 (of 4) in Run 2.

Explain how to calculate the time interval during which the ball moves from Position 2 to Position 3 (of 4) in Run 2.
Graphs: (Include a graph and answers to the following questions in your lab notebook)

Plot a position vs. time instant graph (on graph paper) using your data for each run. This will be a multiple line graph so you will need to include a legend (colored pencils are recommended). Draw a best-fit line for each run. If your data does not look linear, ask for help with the best-fit line.

Find the slope of the best-fit line for each run. (Include the units!)

Write the equations for each line. How does each equation describe the motion of the ball? Explain. (Hint: Remember y=mx+b. Both the slope (m) and the intercept (b) values must have units.)

Group Discussion Questions: Make sure that you know how to do these calculations if asked.

What do the units tell you about the meaning of the slope of the line on a position-vs-time graph?

What is correct for finding the average velocity – the position and time instant, or the displacement and time interval?

Plug in values from Run 2 to explain why \( \frac{x}{t} \) will not yield the velocity.

Trends and Patterns: (Include a answers to the following questions in your lab notebook)

How are the three lines on your graph different? What does this tell you about their differences in motion? Explain.

How are the three lines the same? What does this tell you about the similarities in the motion? Explain.

Group Discussion Questions: Make sure that you know how to do these calculations if asked.

Compare Runs 1 and 2. Which quantities (of x, t, Δx, and Δt) are different with the meter stick shifted? Which are not?
Applying What You’ve Learned About Motion Graphs

**Group Discussion Questions:** Make sure that you know how to make these types of readings from an x vs. t graph.

Unless specified otherwise always take readings from the best fit line.

Show the following information for **position and displacement** on your graph. Use arrows or colored pencil to point out where one should look on the graph to make these readings. Make sure that you graph clearly distinguishes between the reading of position and displacement.

a.) The position of the ball at 0.75 sec for Run 2.

b.) The displacement of the ball between its position when t=0.75 sec, and its position when t = 1.0 sec for Run 2.

Show the following information for **time instant and time interval** on your graph. Use arrows or colored pencil to point out where one should look on the graph to make these readings. Make sure that you graph clearly distinguishes between the reading of time instant and time interval.

c.) The time instant when the ball reaches the position x = 18 cm in Run 3.

d.) The time interval between when the ball is at position x=18 cm, and the position x=43 cm.

Show how to read/calculate the **average velocity**. Use arrows and colored pencil to point out where one should look on the graph to make the readings to be used in the calculation.

e.) The average velocity for Run 2.

Show how to read/calculate the information for the **initial position**. Use arrows and colored pencil to point out where one should look on the graph to make this reading.

f.) The initial position of the ball in Run 2.