Motion in One Dimension

1 INTRODUCTION

There is a close connection between the *position*, *velocity*, and *acceleration* of an object. This lab will explore how these three quantities are related as an object moves in one dimension.

2 LEARNING OBJECTIVES

At the conclusion of this activity you should be able to:

- Design an experiment to measure the position of an object as a function of time.
- Identify the relationship between position, velocity, and acceleration using graphs.
- Compare two measured numbers.

3 BACKGROUND

3.1 READING ASSIGNMENT

The pre-lab quiz for this experiment is based on readings from John R. Taylor's "An Introduction to Error Analysis". Please read:

- Chapter 2.5: Comparison of Two Measured Numbers (pp. 20-24).
- Chapter 2.6: Checking Relationships with a Graph (pp. 24-28).

4 GETTING STARTED

Follow these instructions to setup your directory structure for this assignment.

1. **Download the assignment .ZIP file from Blackboard:** Download the assignment file: `ComparingValuesNB.ZIP` from Blackboard. Move the downloaded file to your 🗀`AS_173_115` directory.
2. **Extract the assignment file:** Unpack the contents of the .ZIP file by double-clicking (Mac) or right-clicking and selecting "extract" (Windows). When it is unpacked, it will have created a new folder called 🗀`ComparingValuesNB`. Once unpacked, you can safely delete the original .ZIP file.
3. **Launch Anaconda-Navigator:**
4. **Launch Jupyter Notebook:**

5. **Open the assignment notebook:** Navigate to your 🗀 `AS_173_115` ▸ `ComparingValuesNB` directory in the Jupyter Notebook dashboard. Open the Jupyter Notebook by clicking on: `ComparingValuesNB.ipynb`.

> **Homework:**
> The idea is that you will spend some time going through the `ComparingValuesNB.ipynb` tutorial on your own *before coming to the next class.*
> **Lab Work:**
> We will work on the rest of the assignment in the lab with you when we meet next time.

4.1 Velocity

The average velocity is given by the total distance traveled Δx, divided by the elapsed time Δt:

$$v_{\text{average}} \equiv \frac{\Delta x}{\Delta t}. \tag{4.1}$$

The *instantaneous* velocity is found by shrinking the elapsed time to smaller and smaller slices of time, dt. In the limit that $dt \to 0$, we arrive at the familiar calculus-based definition of velocity, where the velocity is the derivative of displacement with respect to time:

$$v = \frac{dx}{dt}. \tag{4.2}$$

If the position of an object is plotted as a function of time then the slope at any given point is the velocity. An object moving with a constant velocity will have a constant slope, as shown in Figure 4.1. An object moving under constant acceleration will exhibit a parabolic shape, as shown in Figure 4.2.

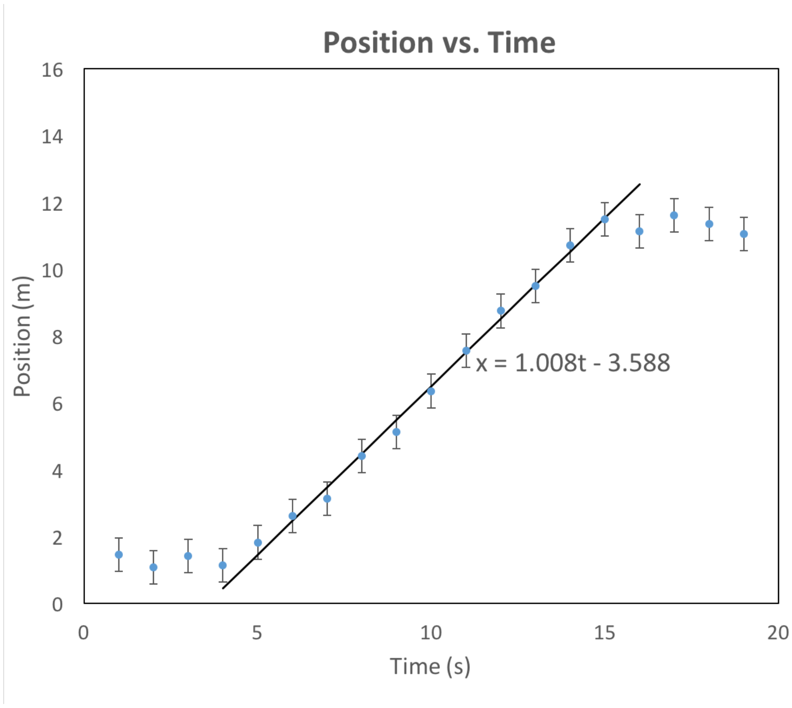

Figure 4.1: An example of some position data plotted as a function of time. For $t < 5s$, the object appears to be at rest. Between $t = 5$ and $t = 15s$ the object is changing its position. At $t > 15s$, the object appears to be again at rest. The data between $t = 5$ and $15s$ are modeled with a straight line: $x = vt + x_o$. The line appears to describe the data well, suggesting that the measured object was moving with a constant velocity given by the slope of the line. In this case, the fit model gives $v \approx 1 m/s$.

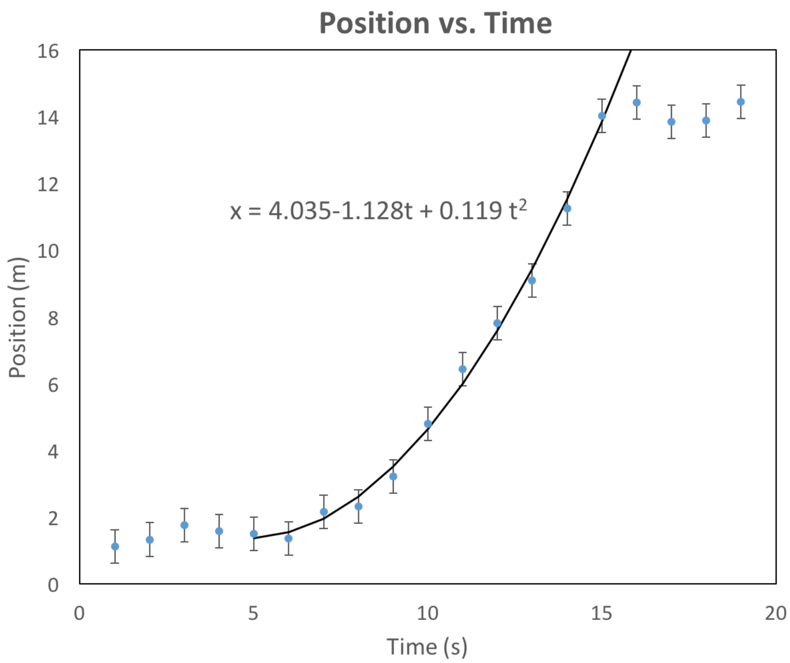

Figure 4.2: An example of some position data plotted as a function of time. For $t < 5s$, the object appears to be at rest. Between $t = 5$ and $t = 15s$ the object is changing its position. At $t > 15s$, the object appears to be again at rest. The data between $t = 5$ and $15s$ are modeled with a parabolic function: $x = x_o + v_o t + \frac{1}{2}at^2$. The fit appears to describe the data well, suggesting that the measured object was moving with a constant acceleration given by the second derivative of the parabola. In this case, $a_{\text{measured}} = 2 \times 0.119 \approx 0.24 m/s^2$. The instantaneous velocity at points between $t = 5$ and $15s$ is given by the first derivative of the position.

5 Procedure

The goal of this activity is to measure the position and velocity of a toy car.

5.1 Experiment with Motion Detector

Another team of scientists measured the same car using a different apparatus. Their method, analysis, data and results are available on Blackboard: `MotionDetectorAnalysis.zip`.

5.2 Design an Experiment

Design an experiment to mesure the position and velocity of the same toy car. You have access to the following tools:

- A stack of sugar packets
- A meter stick
- A metronome

A metronome app can be installed on your smart phone for use in this experiment.

Web Browser Based Metronome on your Computer: • Try googling "online metronome" Suggested iOS Metronome Apps: • "Pro Metronome" • "Steinway Metronome" Suggested Android Metronome Apps: • "Pro Metronome" • "Metronome Beats"

Use your data to create a plot of the distance the car travels as a function of time.

Using your plot, determine the velocity (and associated uncertainty) of the toy car.

6 Comparing Two Measured Numbers

Compare your measured velocity of the car (from Section 5.2) with that from Section 5.1.

- What is the discrepancy between the measurements?
- Is the difference between the measurements significant?
- Which measurement is most trustworthy?

7 Lab Notebook

Your notebook should be a complete record of what steps you took for your analysis. You should include equations, pictures, figures, diagrams, etc to clearly record your ideas and work.