

# Kinematics in One Dimension

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## Equipment

- Computer with Excel software
- PASCO Interface
- PASCO Motion Sensor (either Black or Blue)
- Beach Ball

## Objectives

- *To compose and verify kinematics equations describing the motion of a ball in the air.*

## Introduction

Kinematics is the description of motion. When describing the motion of an object, it is essential to know its position relative to a reference point, how fast and in what direction it is moving, and how it is accelerating (changing its rate of motion). A sonar ranging device such as the PASCO Motion Sensor uses pulses of ultrasound that reflect from an object to determine the position of the object. As the object moves, the change in its position is measured many times each second. The change in position from moment to moment determines the velocity (in meters per second). The change in velocity from moment to moment determines the acceleration (in meters per second per second). The position of an object at a particular time can be plotted on a graph. You can also graph the velocity and/or acceleration of the object versus time. A graph is a mathematical picture of the motion of an object. For this reason, it is important to understand how to interpret a graph of position, velocity, or acceleration versus time.

The setup for this experiment consists of a motion sensor to determine the distance between the object and the sensor, a Lab Interface that communicates the data obtained by the motion sensor to the PC, and the PC. A beach ball will be the object in motion.



**Figure 1.** The PASCO 850 Interface and the two types of motion sensors: the Blue motion sensor (plug into PasPort 1) and the Black motion sensor (plug into Digital Inputs 1 & 2)

## Part #1: Collecting the Data

*The Data was collected for you in advance. Each group will find a print screen of Capstone Data Table and Graph in the group's File Exchange folder.*

1. In a blank Excel spreadsheet, build a data table of 4 columns and at least 15 rows. Label the table as Table 1: Measured values of ... (finish the label yourself). The columns should be labeled: time, time adjusted, position, and velocity with appropriate units.
2. Type in corresponding values for points highlighted in Capstone Data Table (from all three columns: time, position, and velocity). Leave column "Adjusted Time (s)" blank for now.
3. In "Adjusted Time (s)" column, adjust the time axis so that the first point is  $t = 0$ . To do this, adjust the time values by subtracting the initial time from each time value. The adjusted Time formula is similar to: `=A2-11.28`. Use the time of your first point.

## Part #2: Analyzing the Data in Excel

Watch [Excel Videos](#) Parts 1, 2, and 3 from Auxiliary Downloads to learn how to analyze data with Excel. Compose two more tables, Table 2 and Table 3, see below.

1. **For Table 2**, determine the Time and Position of the following points:
  - Initial: When the ball started its parabolic ascent.
  - Turning Point: When it reached the maximum height.
  - Final: When it reached the lowest point of the parabolic descent.
2. **For Table 3**, use the data in Table 1 to calculate the distance traveled ( $d$ ) by the ball and the displacement ( $\Delta y$ ) of the ball during that time. Use calculated positions to determine the average speed and average velocity of the ball. Refer to the pre-lab practice.

	Initial	Turning Point	Final
Adjusted Time (s)			
Position (m)			

**Table 2.** Recorded key values of position and time

Distance Traveled, $d$ (m)		Average Speed (m/s)	
Displacement, $\Delta y$ (m)		Average Velocity (m/s)	

**Table 3.** Calculated values related to the position and velocity

3. Make an XY Scatter plot of Position vs. Adjusted Time. Obtain the equation of the best fit for this graph using the Trendline feature. When fitting, choose wisely between a linear, a power, and a polynomial function. Display the equation on the graph. Edit the trendline equation to take out the  $x$  and  $y$  variables that Excel uses and put in  $t$  and  $y(t)$  in their place. Make sure to label the axis and display a title on the graph.
4. Make an XY Scatter graph of Velocity vs. Adjusted Time. Obtain the best fit function  $v(t)$  and make the graph nice, as described above in the Position vs. Adjusted Time section.
5. **In Table 4**, record the trendline equation for Position vs. Adjusted Time graph along with information about acceleration, initial velocity, and initial position that could be extracted from it. Construct an equation  $V(t)$  from the extracted values.
6. **In Table 4**, record the trendline equation for Velocity vs. Adjusted Time graph along with information about acceleration and initial velocity that could be determined from it.

	From Position Plot	From Velocity Plot
Trendline equation	$y(t) =$	$v(t) =$
Acceleration $a$ ( $\text{m/s}^2$ )		
Initial velocity ( $\text{m/s}$ )		
Initial Position		n/a
Composed Model $v(t)$	$V(t) =$	n/a

**Table 4.** Trendlines and values extracted from both, position and velocity plots.

### Part #3: Verifying the Equations

1. Choose any data point from Table 1 when the ball was *ascending*. Record the adjusted time, Position, and velocity at that point **in Table 5**.
2. Choose any data point from Table 1 when the ball was *descending*. Record the adjusted time, Position, and velocity at that point **in Table 5**.
3. Used the adjusted time to calculate the values of position and velocity from both,  $y(t)$  and  $v(t)$  equations that was composed for Table 4. Make the calculations for both, the point of ascend and descend.
4. In a sentence in the abstract, compare the values of position and velocity calculated by the trendline equations correlate with the corresponding values determined by the sensor (measured data).

	Ascending	Descending
Adjusted Time (s)		
Actual Position from Capstone Data (m)		
Predicted Position calculated with $y(t)$ equation (m)		
Actual Velocity from Capstone Data (m/s)		
Predicted Velocity calculated with $v(t)$ equation (m/s)		

**Table 5.** Positions and Velocities extracted from the Capstone Data table, from the Excel Data Table, and from the Excel Trendlines.

## Part #4

With Motion Sensor measurements, a positive direction (sign) is defined as the direction away from the sensor. Allocate the sign to the velocity and acceleration for the following cases.

Situation	Sign of the Initial Velocity	Sign of the Acceleration
The sensor is placed on the floor and the ball is tossed up above the sensor		
The sensor is placed on the floor and the ball is dropped down towards the sensor		
The sensor is attached to the ceiling and the ball is tossed towards the sensor		
The sensor is attached to the ceiling and the ball is dropped beneath the sensor		

## Requirements for the Report:

***Only one report needs to be submitted per lab group from the Blackboard***

***“Report Submissions” page.*** The names of the lab partners collaborating on the report must be listed in the header on each page of the report; a lab partner whose name is not listed will not receive the credit unless separate report is submitted individually (such report will have 5 points deduction for the team work).

- The **abstract section** must contain the following explanations in paragraph form:
  - Origin of the data including the transfer of the selected parabolic portion of the data from Capstone to Excel and adjustment of time
  - How the data was analyzed including formulas used for computing values in Tables 2 & 3
  - Interpretations of the trendlines of the graphs or how you find acceleration, initial velocity, and initial position from the trendline(s) for Table 4. Use standard  $x(t)$  and  $v(t)$  equations to explain.
  - A statement based on Table 5 about how the measured and calculated values (position and instantaneous velocity) correlate. Were they close (they should be)? Why?
- The **data section** must include
  - 5 Tables (labeled and captioned)
  - 2 Graphs labeled as Figures 1 and 2 and captioned

If there was a “division of labor” between lab partners, the report must include a credits section at the end listing the authors of each section. (Example: The Excel graphs were done by ....; the Data tables were done by ...; the abstract was written by ...)