Kinematics in One Dimension

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

1. Attach the sensor as appropriate.
2. Load the appropriate Capstone file from Physics Laboratory page. Choose the Tab corresponding to the Position vs. Time graph for your motion sensor (blue or black).
3. Place the Motion Sensor on the table with the metal disc and green LED facing up.
4. To start taking data, click "Record" button (lower left corner of Capstone).
5. Toss the beach ball straight up above the sensor and catch it before it hits the sensor.
6. After you catch the ball, click Stop.

- *A successful run should have a portion that is perfectly parabolic, with at least 12 data points, and no spikes. If there is no good parabolic curve, simply repeat from step 1.*

7. Highlight the parabolic portion of the Position graph with "Highlight" tool  .

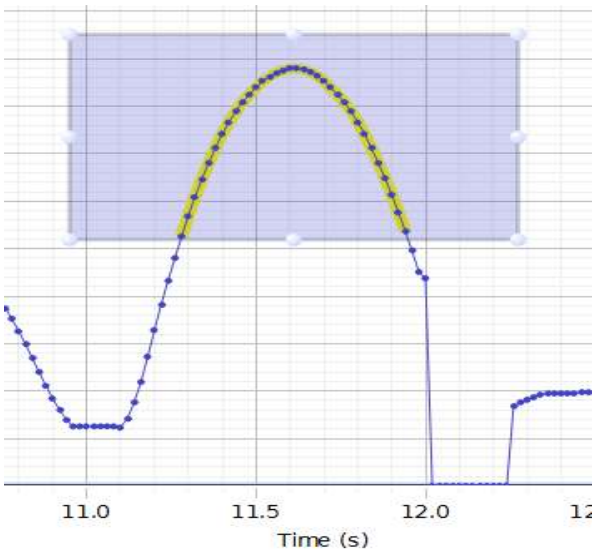

Figure 2. Sample of the highlighted parabolic portion of the data.

8. In Capstone Data Table, select the highlighted points (all three columns: time, position, and velocity), copy them to the clipboard and paste the data into Excel. Delete the first row that says "Auto, Run #, Run #".

9. In Excel Data Table, adjust the time axis so that the first point is $t = 0$. To do this, insert a column just to the right of the original time, and call it "Adjusted Time (s)". In this column, 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.

10. ***DO NOT close the Capstone Software!*** It is not for collecting data only but for the data analysis as well.

Part #2: Analyzing the Data in Excel

1. **For Table 1**, 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 2**, use the data in Table 1 to calculate the distance traveled (d) by the ball and the displacement (Δy) 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 1. Recorded key values of position and time

Distance Traveled, *d* (m)		**Average Speed (m/s)**	
Displacement, Δy (m)		**Average Velocity (m/s)**	

Table 2. 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 3**, 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 3**, 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 (m/s^2)		
Initial velocity (m/s)		
Initial Position		n/a
Composed Model $v(t)$	$V(t) =$	n/a

Table 3. Trendlines and values extracted from both, position and velocity plots.

Part #3: Verifying the Equations

1. **Back in Capstone**, choose any point on the Position vs. Time graph when the ball was ascending. Find the time, Adjusted Time, position, and slope of the graph at that point. Record these values in Table 4.
   For Table 4, use two tools located at the toolbar at the top of the graph:
   -  The Coordinate tool lets you see the Time and Position values of a chosen data point.
   -  The Tangent Line tool shows you the slope at a point. After clicking on the tool, find the little dashed line, and drag it around until it points at the data point you are interested in. After you drop it onto the data, it looks like a solid tangent line the same color as your data.

2. Choose any data point on the Position graph when the ball was descending. Record the time, Position, and slope of the graph at that point in Table 4.

3. Used the adjusted value of the chosen time to calculate the values of position and velocity from both, $y(t)$ and $v(t)$ equations. Make the calculations for 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.

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

Table 4. Positions and Velocities extracted from the Capstone Position vs. Time graph, from the Excel Data Table, and from the Excel Trendlines.

Requirements for the Report (also consult the rubric):

Save your Excel files through your Blackboard Group File Exchange

- The **abstract section** must contain the following explanations in paragraph form:
  - How the data was collected including the selection and transfer of the parabolic portion of the graph in capstone 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 (how did you find acceleration, initial velocity, and initial position from the trendline(s)? Use standard $x(t)$ and $v(t)$ equations to explain.)
  - A statement based on Table 4 about how the measured and calculated values (position and instantaneous velocity) correlate. Were they close (they should be)? Why?
- The **data section** must include
  - 4 Tables (labeled and captioned)
  - 2 Graphs labeled as Figures 1 and 2 and captioned

Exit Questions: must be completed before exiting lab

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.

You may use the sensor to see the sign of the values in the collected data

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		