

Position, Velocity and Acceleration

Equipment

Qty	Equipment	Part Number
1	Dynamic Track	ME-9493
1	Cart	ME-9454
1	Fan Accessory	ME-9491
1	Motion Sensor II	CI-6742A
1	Track Barrier	

Purpose

The purpose of this activity is to study some of the basic behaviors of a mass that is being uniformly accelerated; that means, experiencing a constant acceleration.

Theory

Displacement is defined to be the straight line length measured from what is taken to be the initial position, and the final position.

$$\Delta x = x - x_o$$

The average velocity is defined to be the time rate of change of position, therefore it is the displacement divided by the time interval the displacement took place over.

$$v_{avg} = \frac{\Delta x}{t} = \frac{x - x_o}{t}$$

The average acceleration is defined as the time rate of change of velocity, therefore it is the average velocity divided by the time interval the change in velocity took place over.

$$a_{avg} = \frac{\Delta v_{avg}}{t} = \frac{v - v_o}{t}$$

For a mass to be accelerated uniformly, the value of the acceleration must be constant, meaning it always has the same value, and therefore in such a case we can drop the 'avg' subscript for the acceleration in the above equation.

$$a = \frac{v - v_o}{t}$$

When the acceleration a mass is experiencing is constant we say that that mass is being uniformly accelerated. Since acceleration is the time rate of change of velocity, then for a mass being uniformly accelerated, its velocity will be changing at a constant rate such that its average velocity will also be given by the following equation.

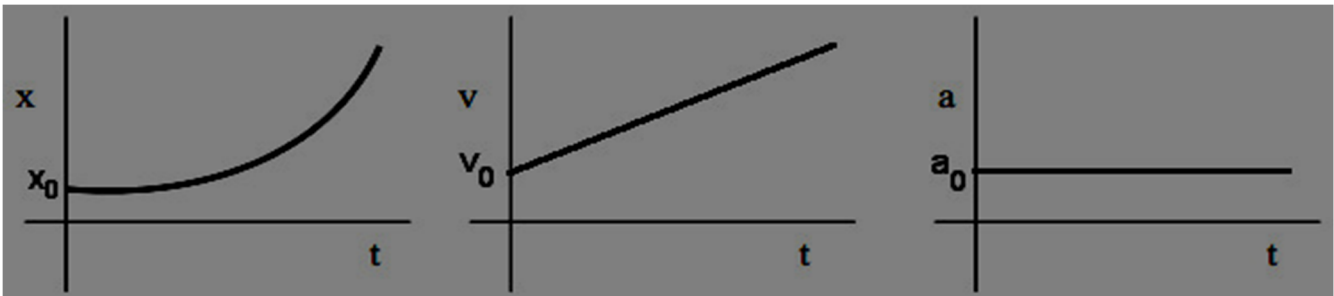
$$v_{avg} = \frac{v + v_0}{2}$$

This equation tells us that for a mass being uniformly accelerated its average velocity is just the average value between its initial and final velocities. Keep in mind that *this equation is only true for masses experiencing uniform acceleration!*

Just using these definitions, and with the assumption of uniform acceleration, we can easily construct the Linear Kinematic Equations of Motion. Some of the equations we can construct are the following

Uniformly Accelerated Motion
$a = a_0$ (constant value)
$v = v_0 + at$
$x = x_0 + v_0t + \frac{1}{2}at^2$

Plotting these three equations out as functions of time will yield graphs similar to the following;



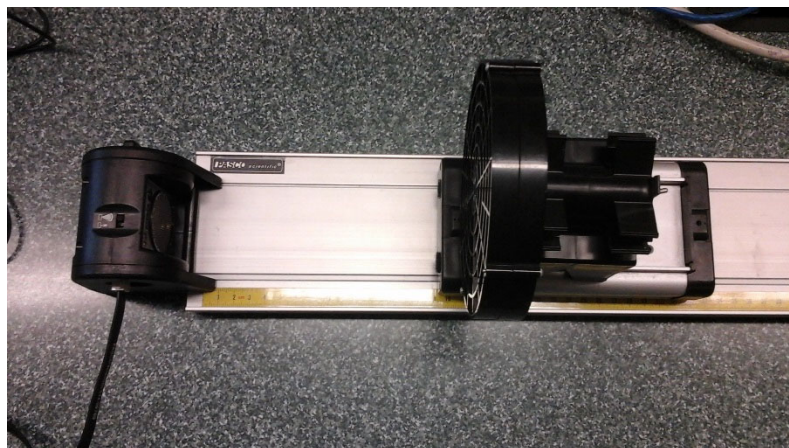
A concept that is rarely discussed in freshman physics classes is the jerk. The average jerk is defined to be the time rate change of the acceleration; therefore, it is the change in acceleration divided by the time interval the change in acceleration took place over.

$$J_{avg} = \frac{a - a_0}{t}$$

In this exercise we will be ignoring whatever little jerk there might be.

Setup

1. Lay the track flat on the table.
2. Attach the motion sensor to the end of the track closest to the PASCO 850 Interface.
 - Don't just place the motion sensor next to the end of the track. It is designed to be physically attached to the end of the track.
 - Plug the motion sensor into Digital Inputs Ch(1), and Ch(2) of the PASCO 850 Interface. Yellow goes into Ch(1), black into Ch(2).
 - Using the nob on the side of the Motion Sensor make sure the sensor is aimed horizontally down the length of the track.
3. Attach the fan accessory to the cart.
4. Place the cart onto the track with the fan pointing at the motion sensor
 - There needs to be 15 cm between the back of the cart and the motion sensor.
5. At the other end of the track, attach the barrier to prevent the cart from falling off the track when performing the experiment.
6. Make sure the PASCO 850 interface is turned on.
7. Double Click the Capstone icon to open the Capstone software.
8. In the Tool Bar, on the left hand side of the screen, click on the Hardware Setup icon to open the Hardware Setup window.
 - In the Hardware Setup window there should be an image of the PASCO 850 Interface, if there is skip to step 9. If there isn't click on Choose Interface to open the Choose Interface window. In the Choose Interface window chose PASPORT, Automatically Select, then click OK.
9. On the image of the 850 PASCO Interface click on Digital Inputs Ch(1).
 - This will open a sensor list. Scroll down and select Motion Sensor II.
 - At the bottom of the screen, set the sample rate to 20 Hz.
10. In the Tool Bar click on the Data Summary icon, this will open up the Data Summary window.
 - Next to where the Motion Sensor II is listed in the Data Summary window click on the white triangle to open up the measurements list for the Motion Sensor.



- Click on the word 'Acceleration'. This should cause a property icon to appear to its right. Click on it and the properties window for the acceleration measurements should open.
 - Click on Numerical format and set Number of Decimal Places to 3, and then click Ok.
11. Close the Tool Bar.
 12. In the Display Bar, on the right side of the screen, click-drag out-and release the graph icon three times.
 - For one of them for the y-axis click on Select Measurement, and then select Position (m).
 - For another for the y-axis click on Selection Measurement, and then select Velocity (m/s).
 - For the y-axis of the third click on Selection Measurement, and then select Acceleration (m/s²).
 - The computer will automatically set the x-axis to Time (s) for all of them.

Procedure

1. Place a finger right in front of the cart to hold it in place, and then turn on the fan accessory.
2. At the bottom left of the screen, click on the big red circle to start recording data, and quickly remove your finger allowing the cart to be accelerated down the track.
3. When the cart bumps into the barrier at the opposite end of the track click on the big red square at the bottom left side of the screen to stop recording data.
4. Turn off the fan accessory.
5. For each graph, click on the Scale Axes icon so you can see your data much more clearly.
 - It is the far left icon at the top of each graph.
6. **For the Position vs. Time graph** click on the Highlight range icon at the top of the graph to make the highlight box appear in the Position vs. Time graph.
 - Move the box around by left-click-and-dragging, and stretch the box such that all the data points from when the cart started moving till the cart hit the barrier are highlighted.
 - Click on the down arrow next to the Apply Selected Curve Fit icon to open the best fit line list.
 - Select both the linear fit and Quadratic fit.
 - For the linear fit, record the m and b values in the position table, ignoring the error bars.
 - For the quadratic fit, record the A, B and C values in the position table, ignoring the error bars.
 - Click on the Add a Coordinate Tool icon, and use it to find the coordinate values for the two data points that are right in the middle of the highlighted region of the position graph. Record the values of these two coordinates in the position table with units. Then calculate the slope, with units, between these two points.
7. **For the Velocity vs. Time graph** click on the Highlight Range icon at the top of the graph to make the highlight box appear in the Velocity vs. Time graph.
 - Move the box around by left-click-and-dragging, and stretch the box such that all the data points from when the cart started moving till the cart hit the barrier are highlighted.

- Click on the down arrow next to the Apply Selected Curve Fit icon to open the best fit line list.
 - Select the linear fit.
 - Record the values for m and b in the Velocity Table, ignoring the error bars.
 - Click on the Add a Coordinate Tool icon, and use it to find the coordinate values of the first data point and the last data point that is highlighted in the velocity graph, and record these values, with units, in the table for the velocity graph. Then use these two values to find the average value of the velocity and record it in the velocity table.
 - Use the Coordinate Tool to find the time when your calculated average velocity occurred and record it in the velocity table with units.
8. **For the Acceleration vs. Time graph** click on the Highlight Range icon at the top of the graph to make the highlight box appear in the acceleration vs. Time graph.
- Move the box around by left-click-and-dragging, and stretch the box such that all the data points from when the cart started moving till the cart hit the barrier are highlighted.
 - Click on the down arrow next to the Apply Selected Curve Fit icon to open the best fit line list.
 - Select the linear fit.
 - Record the values for m and b in the Acceleration Table, ignoring the error bars.
 - Click on the down arrow next to the Display Selected Stats icon to open the stats list.
 - Make sure Mean is selected, then click on the down arrow again to close list.
 - Click on the Display Selected Stats so the value of the Mean will appear on the Acceleration vs. Time graph, and record the value of the Mean in the Acceleration Table.

Analysis of Position, Velocity and Acceleration Lab

Name _____ Group# _____

Course/Section _____

Instructor _____

Table (16 points)

Position vs Time	Value
Linear Fit	
m	
B	
$y = mx + b$	
Quadratic Fit	
A	
B	
C	
$y = Ax^2 + Bx + C$	
(x_1, y_1)	
(x_2, y_2)	
Slope	

Velocity vs. Time	Value
m	
b	
$y = mx + b$	
(x_1, y_1)	
(x_2, y_2)	
v_{avg}	
v_{avg} time	

Acceleration vs. Time	Value
m	
b	
$y = mx + b$	
The mean	

1. What are the appropriate units for the slope of the:

(a) Position vs Time graph? (2 points)

(b) Velocity vs Time graph? (2 points)

(c) Acceleration vs Time graph? (2 points)

2. For Position vs Time data:

(a) Did your quadratic fit of this graph provide initial position? If yes, what is its value?
(4 points)

(b) Did your quadratic fit of this graph provide initial velocity? If yes, what is its value?
(4 points)

(c) Did your quadratic fit of this graph provide acceleration? If yes, what is its value?
(4 points)

(d) What specific physical quantity does the slope of the two middle points from the Position vs. Time graph represent?
(4 points)

3. For Velocity vs Time data:

(a) Did your linear fit of this graph provide initial position? If yes, what is its value?
(4 points)

(b) Did your linear fit of this graph provide initial velocity? If yes, what is its value?
(4 points)

(c) Did your linear fit of this graph provide acceleration? If yes, what is its value?
(4 points)

- (d) How does the time your calculated average velocity occurred at compare to the times of the two middle points from the position vs. time graph? (3 points)

- (e) How does the time your calculated average velocity value occurred at relate to the time values of the first and last good data points in the Velocity vs. Time graph? (3 points)

4. For Acceleration vs Time data:

- (a) Did your linear fit of this graph provide initial position? If yes, what is its value? (4 points)

- (b) Did your linear fit of this graph provide initial velocity? If yes, what is its value? (4 points)

- (c) Did your linear fit of this graph provide acceleration? If yes, what is its value? (4 points)

- (d) Which method, the mean or the linear fit, gives an acceleration value that in better agreement with the values of acceleration given by the position and velocity data? (2 points)

- (e) Did your linear fit of this graph yield Jerk? If yes, what is its value? (5 points)

- (f) If Jerk was observed, was its value small enough to be neglected (i.e., close to zero)? (5 points)

- (g) What are the SI units of the Jerk? (2 points)

5. Starting from $F = ma$, and using calculus, derive $v = v_o + at$ and $x = x_o + v_o t + \frac{1}{2}at^2$. (15 points)

6. Name at least one physical source of error for this experiment. Do not include human error, equipment malfunction or rounding errors. (4 points)

7. Can the Linear Kinematic Equations of Motion be used in a situation in which the acceleration varies with time? (4 points)

8. What is the general shape of each graph and why does each have that shape? (10 points)