

Kinematics of One-Dimensional Motion: Motion of a Cart on a Ramp

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Using the given datasets, we want to analyze the motion of a cart along an inclined plane. These datasets contain information about the position, velocity and acceleration of the cart as a function of time. The data was collected using two different angles – three files correspond to each angle. This allows us to get accurate values for calculations throughout the lab.

Part 1:

First we need to collect some data, set your ramp to a reasonable angle/height. We want to record the motion of the cart, this should be fairly constant when using the spring launcher and a set pull back distance. Using the PASCO program available on the computer, create 3 plots within the same trial. This can be done by simply adding additional plots in the toolbox towards the top of the plots. Once three plots have been added to the same trial, you need to select which values you wish to have displayed on each of the plots. To do this right click on the y-axis label and select the specific function, you should have a graph for position, velocity, and acceleration.

Run a trial, releasing the cart and allowing it to go up the ramp, and return back to the starting point. You should see that the data for the x, v, a are now shown on the graphs; and it should become clear that there is a lot of “noisy” data on either end of cart moving in its path (typically a section of zero motion shows before the cart is launched and a lot of back and forth is seen if the cart hits the spring again and bounces around after the motion).

To deal with this data we are going to need to remove all of the data where the cart is not moving up and down the hill solely under the effects of gravity. We want to export the data and upload it to an excel spreadsheet for further analysis. Extract the data, and copy it into an excel spreadsheet. You should have a column for time, x , v , and a . Next we want to remove as much unnecessary data as possible. Using the plots as a guide, look for the time when the cart begins to move; you may delete or ignore all of the data – including the other columns x, v, a before this time. (If desired, although it won't affect final answers, you can renormalize your time to begin at 0 by simply subtracting the time it took for you to get to data collection from each time). Additionally we need to clean up the data towards the end of the run; it should again, become clear as to when the cart returns to the bottom of the ramp (for example you can use the plots or simply look for where the position returns to the starting value) remove/ignore any data that exists after this end point.

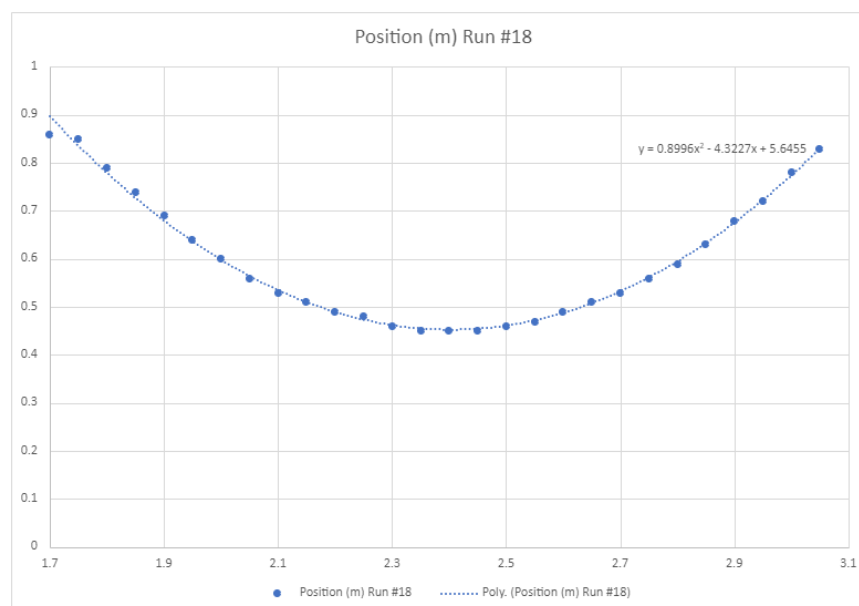
All three plots can be used to determine the acceleration of the cart. To do this we are going to want to fit a trendline to the plots, again this is easiest done in excel. Starting in excel we want to insert -> plot -> scatterplot. Once a scatterplot is added right click on it and add data to the plot. The x-axis for each scatterplot should be time, while the y- axis should be position, velocity, and acceleration (do a different scatterplot for each type of y-value). Once you have plotted the scatterplots, right click on dots in the scatterplot, an option should become available to “add a trendline” to your graph. One requirement when adding a trendline is to tell excel what type of trendline to add – such as exponential vs linear vs polynomial. We need to think about what type of trendline to add for the x vs t , v vs t , and a vs t graphs. Hint: think about the kinematic equations for each of these quantities x , v , a ; how do they relate to time? Make sure to click the “display equation on graph” as well. With the trendline created and the equation shown it should be evident as to what value the acceleration is by matching the trendline equation to the related kinematic equation.

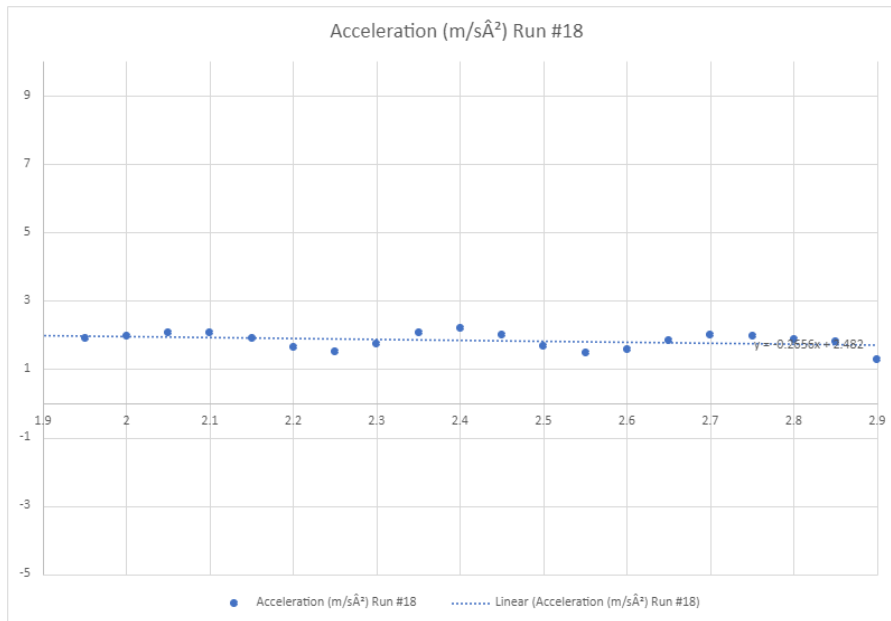
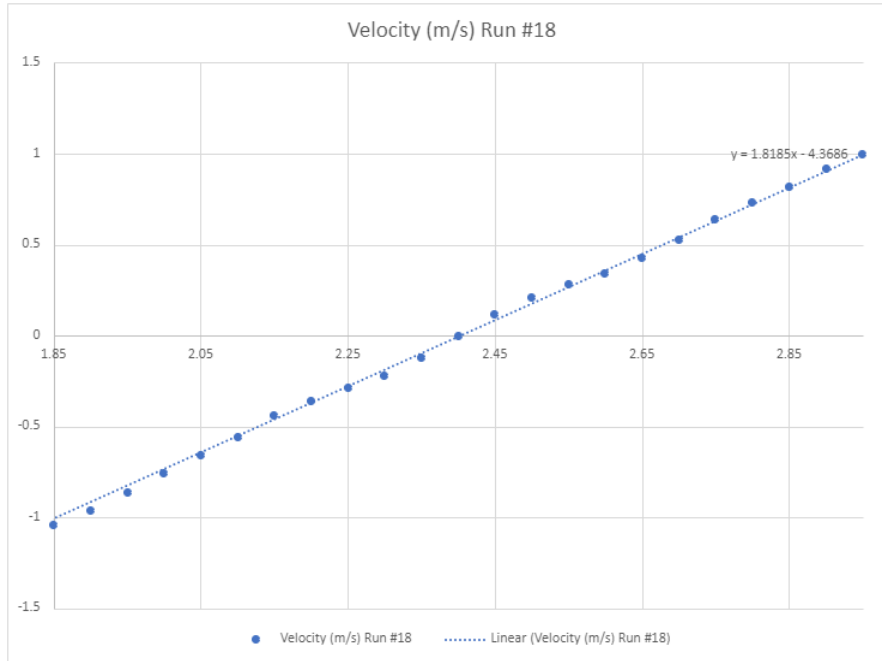
Q1: Fill out table 1 using the data from the trendline fitting

Table 1:

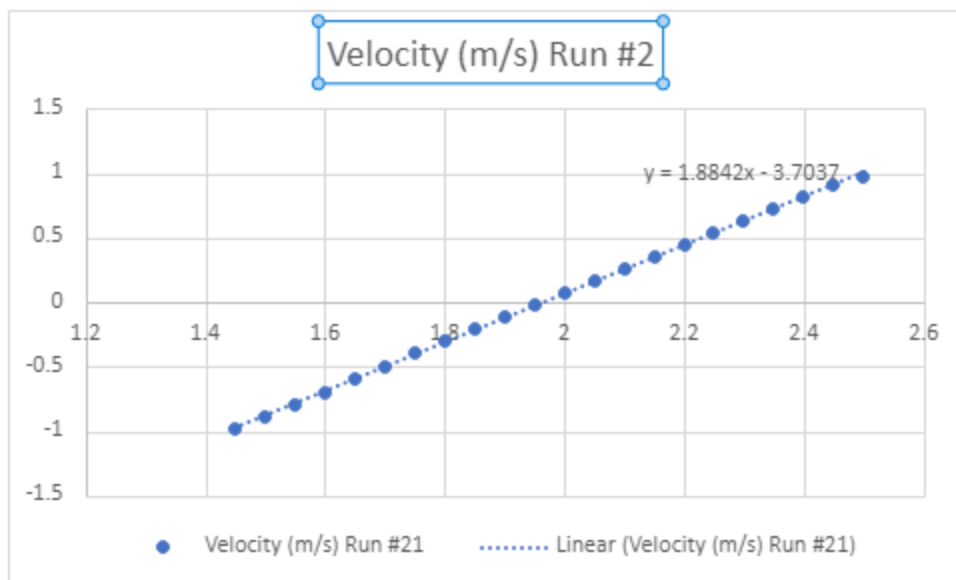
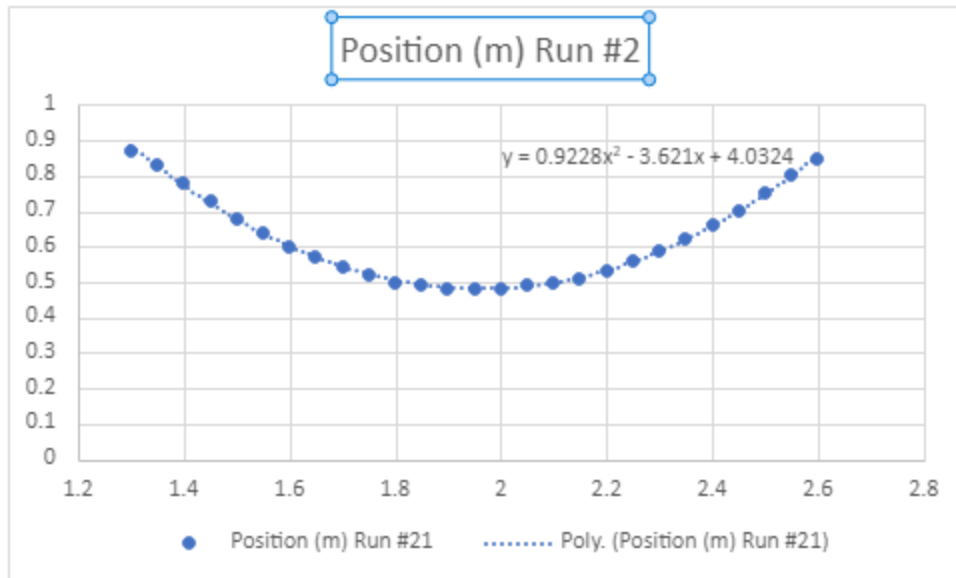
Trial	Acceleration from $x(t)$ fit	Acceleration from $v(t)$ fit	Acceleration from $a(t)$ fit
Trial 1	1.7992	1.8185	1.838
Trial 2	1.8456	1.8842	1.801

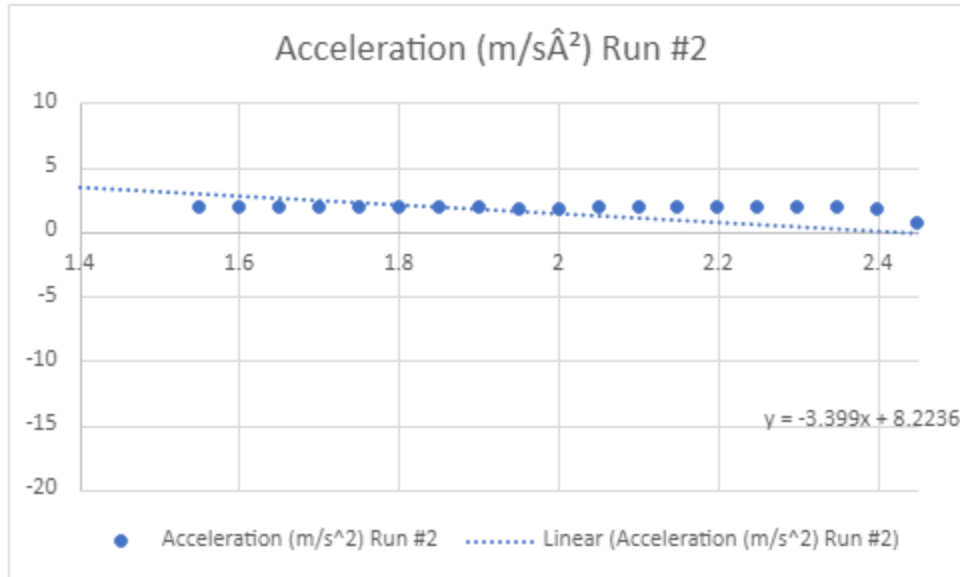
Trial 1 Graphs:





Trial 2 Graphs:





Q2: Using the accelerations we have found from fitting $v(t)$ and taking $g = 9.8 \text{ m/s}^2$, we want to calculate the angle that the ramp is set at. Since we are making measurements, we also want to be sure to include an error along with our value of the angle.

Average acceleration: $1.83 \frac{\text{m}}{\text{s}^2}$

$$a(t) = g \sin \theta$$

$$1.83 = 9.81 \sin \theta$$

$$0.19 = \sin \theta$$

$$\theta = 10.72^\circ$$

Q3: Now calculate the angle of the ramp by using the ruler/meter stick and basic trigonometry. What is your percent error from the calculated angle in Q2 and this measured angle?

$$x = 120 \text{ cm}$$

$$y = 28.2 \text{ cm}$$

$$\arctan(28.2/120) = 13.2 \text{ degrees}$$

$$\theta = 13.2$$

$$\text{error} = (\text{actual} - \text{expected}) / \text{actual} = (13.2 - 10.72) / 13.2 = 0.188$$

$$\text{Percent Error} = 18.8\%$$

PART 2:

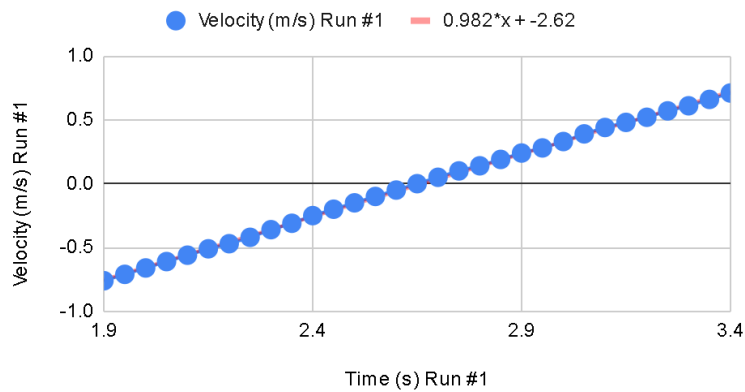
To further see what the angle is doing to influence the gravitational acceleration of the cart, change the angle of the ramp (by changing the height either up or down) and run the experiment again. Because we have only used the $v(t)$ graph in Q2, we can simply take the second set of trials (with the new angle) and only measure, clean, and plot the v vs t graph.

HERE?

Trial	Acceleration from $v(t)$ fit
Trial 1	0.982 m/s^2
Trial 2	0.977 m/s^2

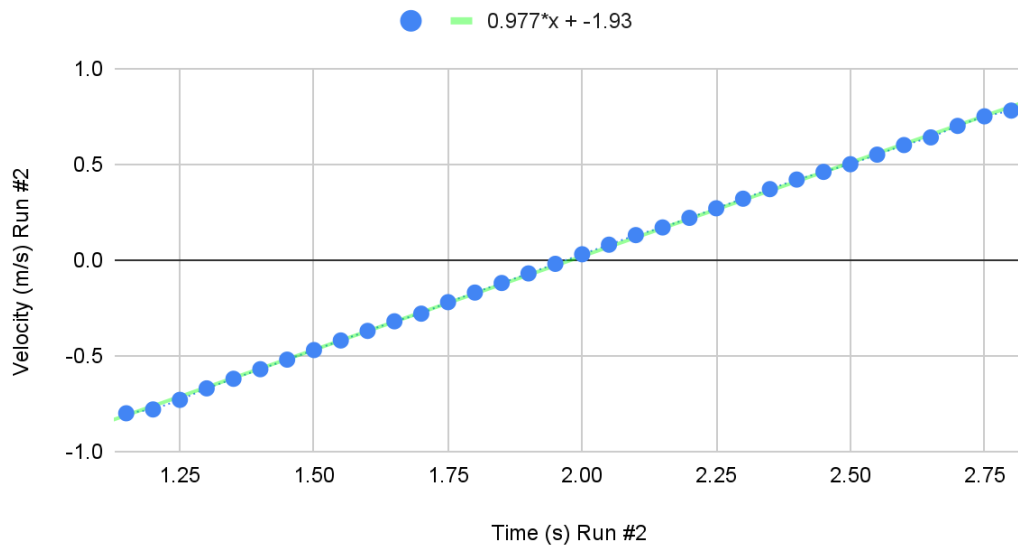
Trial 1 Graph:

Velocity (m/s) Run #1 vs. Time (s) Run #1



Trial 2 Graph:

Velocity (m/s) Run #2 vs. Time (s) Run #2



Q4: Using the accelerations we have found from fitting $v(t)$ and taking $g = 9.8 \text{ m/s}^2$, we want to calculate the angle that the ramp is set at. Since we are making measurements, we also want to be sure to include an error along with our value of the angle.

$$\text{Average Acceleration} = 0.98 \frac{\text{m}}{\text{s}^2}$$

$$a(t) = g \sin \theta$$

$$\sin \theta = a(t)/g$$

$$\sin \theta = 0.98 / 9.81$$

$$\theta = \arcsin(0.98/9.81)$$

$$\theta = 5.73 \text{ degrees}$$

Q5: Now calculate the angle of the ramp by using the ruler/meter stick and basic trigonometry. What is your percent error from the calculated angle in Q4 and this measured angle?

$$x = 120 \text{ cm}$$

$$y = 9.65 \text{ cm}$$

$$\arctan(9.65/120) = 4.6 \text{ degrees}$$

$$\theta = 4.6$$

$$\text{error} = (\text{actual} - \text{expected}) / \text{actual} = (4.6 - 5.73) / 4.6 = 0.246$$

Percent Error = 24.6%

Q6: Does the acceleration of the cart down the ramp depend on the angle that the ramp is set at? As the ramp gets steeper and steeper, what value would we expect the acceleration to get close to? As the ramp becomes more level, what value would we expect for the acceleration?

Yes, the acceleration of the cart down the ramp does depend on the angle that the ramp is set at. As the ramp gets steeper and steeper, we expect the acceleration to get closer to 9.81, the acceleration of gravity. Since the acceleration is increasing, the force of the x-component of the weight of the cart($mg\sin\theta$) increases also, meaning that the cart will travel down the ramp even faster. As the ramp becomes more level, we expect the acceleration to get closer to 0.