Physics 1210
General guidelines for experiment reports

1) Reports should be typed and include tables and graphs, as appropriate, to demonstrate the work and support the conclusions.
2) Reports should include the names of all persons contributing to the work, but should be written by the lead author. Each person should complete their own report.
3) Matlab scripts used to make plots or do computations should be included as an appendix
4) There are no particular font or margins or pages requirements
5) A complete report should include
   - An <u>Abstract</u> stating the main goal, the methods, and the main result or finding.
   - A short <u>Introduction</u> describing why the experiment is being performed
   - A <u>Methods & Data</u> section that describes the experimental setup in both words and with appropriate graphics. This section may also include formulae or derivations needed to demonstrate the objectives of the experiment. The data section should also include tables of data or derived parameters.
   - An <u>Analysis</u> section interpreting the data. This section may also talk about the precision of the results achieved and the main sources of error or uncertainty. This section should include graphs or figures that help interpret the data. Equations or derivations using basic data to compute other parameters may also be included here.
   - A <u>Results & Conclusions</u> section describing what worked well or what could be changed to achieve better results in the future if the equipment or the goals were slightly different.
   - An <u>Appendix</u> (or Appendices), which includes work performed but perhaps not essential to the main body of the report. Things such as Matlab scripts used to make plots should be included in the Appendix.
6) Even though you share data with your group and your data tables may look the same, each report should be unique, reflecting the writing and thinking of each author.
7) The text of the report should follow standard English grammar, punctuation and sentence structure.
8) Grading of experimental reports will follow the rubric distributed to the class
9) An example of a well-written report follows

Experiment 999
Measuring an Acceleration

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Abstract

We measured the acceleration of a HotWheels car down an incline of
constant slope. Observers recorded the distance traveled by the car at
time intervals of 0.5 seconds over the four seconds required for the car to
reach the bottom of the ramp. The position-time data were used to
compute the average velocity in each of eight 0.5-second time intervals.
We then used the change in velocity over each 0.5-second time interval to
compute the acceleration. Our average acceleration over the eight
intervals was 0.469 m/s^2 with a standard deviation of 0.099 m/s^2.

Introduction

Acceleration is a change in the velocity of an object. Generally, an average acceleration may be
expressed as a change in velocity, Δv, over some time interval, Δt.

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

Or, in the limit that Δt goes to zero,

$$a_{avg} = \frac{d v}{d t}$$

Measuring an acceleration, therefore, requires measuring a change in the position of an object and
timing the duration required for each movement. In this experiment, we chose to measure the
acceleration of a race car (really a HotWheels car) down an inclined road (really an orange track). Our
goal was to measure the acceleration of the car to a precision of at least 0.01 meters per second squared
by sing multiple measurements of the car's position over several seconds.

Methods

We set up the race track on an inclined slope made by two metal tracks supported by bricks. Each
metal track was two meters long, so that they form a solid surface four meters long when placed end-to
end. Upon this solid surface we placed several sections of HotWheels track connected together. The
track drops roughly 18 inches over four-meter length. Although we could measure the incline angle to
be roughly 15 degrees, it was not necessary for this experiment. Figure 1 below shows the
experimental setup.

The metals ramps are marked with distance in cm along one edge, making it easy to measure the position of the car at any point along the ramp.
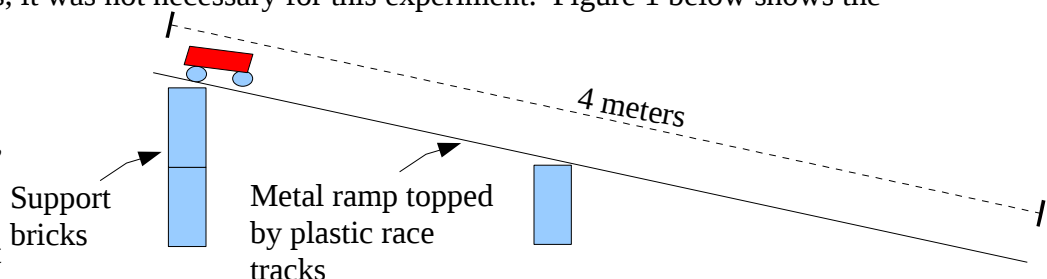

Support bricks

Metal ramp topped by plastic race tracks

4 meters

Figure 1: Schematic of the experimental setup

We released the car from rest at the top of the ramp with the rear end of the car at the zero mark. At each half second interval (e.g., 0 s, 0.5 s, 1.0 s, etc...) we measured the position of the rear edge of the car. Three or four people measured the position of the car at each time interval. We found that was possible to measure the position to an accuracy of at least 1 cm when the car was moving slowly, and each person estimated the position to 1.10 of a cm or 1 mm. However, once the car was moving more quickly, it became harder to measure the position with similar accuracy. We estimate that the positions are accurate to no more than 1 cm. Because several people took data at each time, we record all of their measurements, and we computed an average position at each time in order to help reduce random measurement errors. Table 1 below shows the measurement from each person and the average position of the car at each time.

Table 1. Position, Velocity, Acceleration data

	Measured Data					Calculated parameters	
	Distance	**Distance**	**Distance**	**Distance**	**Distance**	Avg. Velocity	Avg. Acceleration
Time	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	(m/s)	(m/s^2)
(s)	Person 1	Person 2	Person3	Person4	**Average**		
0.00	0.000	0.000	0.000	0.000	**0.000**	0	
0.50	0.065	0.056	0.058	0.069	**0.062**	0.124	0.248
1.00	0.251	0.262	0.240	0.248	**0.250**	0.3765	0.505
1.50	0.562	0.540	0.578	0.569	**0.562**	0.624	0.495
2.00	1.051	1.011	0.980	0.991	**1.008**	0.892	0.536
2.50	1.569	1.530	1.630	1.590	**1.580**	1.143	0.502
3.00	2.256	2.267	2.244	2.239	**2.252**	1.3435	0.401
3.50	3.067	3.040	3.079	3.050	**3.059**	1.615	0.543
4.00	4.010	4.060	3.950	3.967	**3.997**	1.8755	0.521
						Average	**0.469**
						StdDev	**0.099**

Analysis

Figure 2 shows a plot of the position of the car versus time. The plot shows that the car moved farther in any given time interval as the car moved along the ramp. The shape of the curve is roughly that of a parabola.

We computed the velocity of the car during each 0.5 s time interval by taking the distance traveled, Δx, divided by the time interval, Δt.

$$v(m/s) = \frac{\Delta x}{\Delta t} = \frac{(x_2 - x_1)}{(t_2 - t_1)}$$

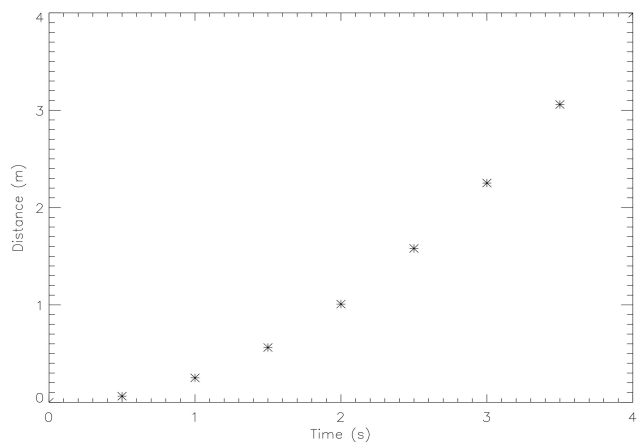For example, after the first 0.5-second time interval, the velocity is

Figure 2: Position of the car in meters versus time using data from Table 1.

$$\frac{\Delta x}{\Delta t}=\frac{(0.062-0.000)}{(0.5-0.0)}=0.124\,m/s$$

The 6th column of Table 1 lists the velocities computed in this manner from each time intervals. Figure 3 below shows a plot of velocity versus time using the data from Table 1. The trend is a approximately a straight line with a positive slope, indicating increasing velocity. A straight line is consistent with a constant acceleration given by the slope of the line. The average velocity of the entire journey is

3.997 meters / 4.0 seconds = 1.00 m/s.

However, the instantaneous velocity is much smaller during the first portion of the experiment and much larger during the latter portion.

Finally, we used the velocity data to compute the acceleration during each time interval. The average acceleration was computed from

$$a_{avg}=\frac{\Delta v}{\Delta t}=\frac{(v_2-v_1)}{(t_2-t_1)}$$

For the first time interval this yields

Figure 3: Velocity of the car versus time.

$$\frac{(v_2-v_1)}{(t_2-t_1)}=\frac{(0.124-0.000)}{(0.5-0.0)}=0.248\,m/s^2$$

The computed accelerations appear in Column 7 of Table 1. The values are relatively constant and fall near 0.5 m/s^2. At the bottom of Table 1 we compute the average acceleration over the eight time intervals to be 0.469 m/s^2 and the standard deviation of this set of data to be 0.099 m/s^2.

Results and Conclusions

We measure the car's acceleration to be a=0.469±0.099 m/s$^{2.}$. We use this value to compute the theoretical distance versus time curve using

$$x_1=x_0+v_0t+\frac{1}{2}at^2 \quad ,$$

where v$_0$=0 is the car's initial velocity and x$_0$=0 is the car's initial position. Figure 4 shows the position-time plot of the data (asterisks) and the theoretical position-time curve (solid line). There is good agreement between the data and the curve, suggesting that the stated acceleration is a good representation of the car's motion overall. However, the curve falls increasingly below the data at later times, suggesting that we have underestimated the acceleration. We notice that our first computed acceleration in Table 1 is about half of the other values. If we reject this one measurement and compute an average of the remaining data, we find an average acceleration of 0.501, which would provide a better fit to the data. We don't have a good explanation for why our first acceleration value is low compared to the others, but it may have to do with difficulties in timing the very first measurement at t=0.5 s. We conclude that we have measured the acceleration reasonably well.

In order to make a better measurement we might use a longer track so that we would have even more
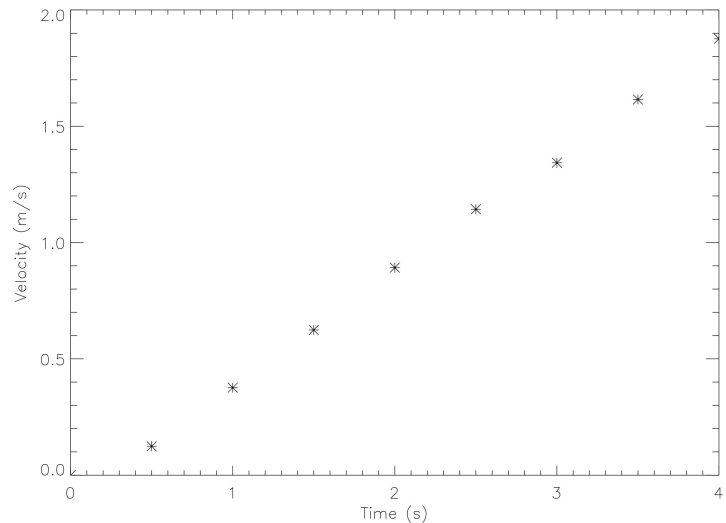
data points and a longer time over which to conduct the experiment. We could also have more people time the car at various points along the track so that, with more measurements, our data would be more accurate over each time interval.   We could also try using a steeper track. We suspect that perhaps friction in the car's wheels would prevent the car from accelerating as quickly as it might otherwise if the track were steeper.
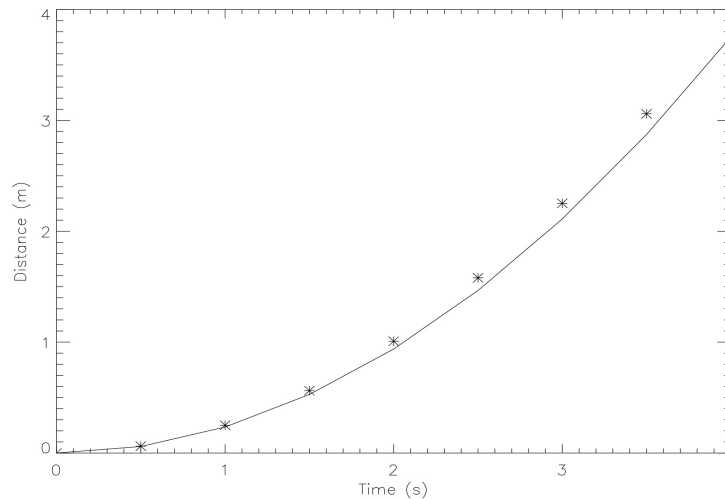

Figure 4: The position of the car versus time, showing the data (asterisks) and the theoretical curve computed using the average acceleration (solid line).

Appendix

Below we show the Matlab code used to make the plots in Figures 2,3,4.

```
% make distance time plot in Figure 2
t=[0.0,0.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0]
x=[0.000,0.062,0.250,0.562,1.008,1.580,2.252,3.059,3.997]
plot(t,x,'bs')
xlabel('Time (s)')
ylabel('Distance (m)')
% make velocity-time plot for Figure 3
t=[0.0,0.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0]
v=[0.0,0.124,0.376,0.624,0.892,1.143,1.343,1.615,1.876]
plot(t,v,'rs')
xlabel('Time (s)')
ylabel('Velocity (m/s)')
% make distance-time plot for Figure 4 with theoretical curve overplotted
t=[0.0,0.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0]
x=[0.000,0.062,0.250,0.562,1.008,1.580,2.252,3.059,3.997]
plot(t,x,'rs')
hold on
a=0.469
plot(t,0.5*a*t.^2)
xlabel('Time (s)')
ylabel('Distance (m)')
```