Lab 1

Gravity and Human Reaction Time

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Physics 100

10/23/2007

Objective/Purpose

The purpose of this lab was to calculate '*g*'.

Equipment/Procedure

Equipment:

1. Photo Gates (x2)
2. Electronic Timer
3. Meter Stick
4. Clear Plastic Tube
5. Wooden Ball (for dropping)
6. Assorted books, tables, and chairs (for height)

Procedure:

We attached the clear tube to a table to keep the falling objects contained and connected the two gates to the timer. Using the books and the chairs we were able place the gate(s) at different heights in ~10 cm increments up to ~120 cm. The details are as follows:

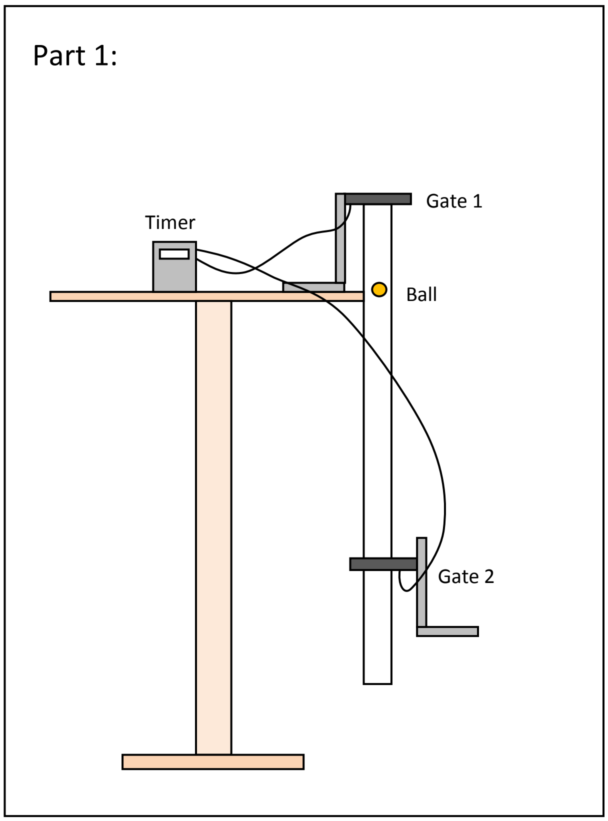
Part 1

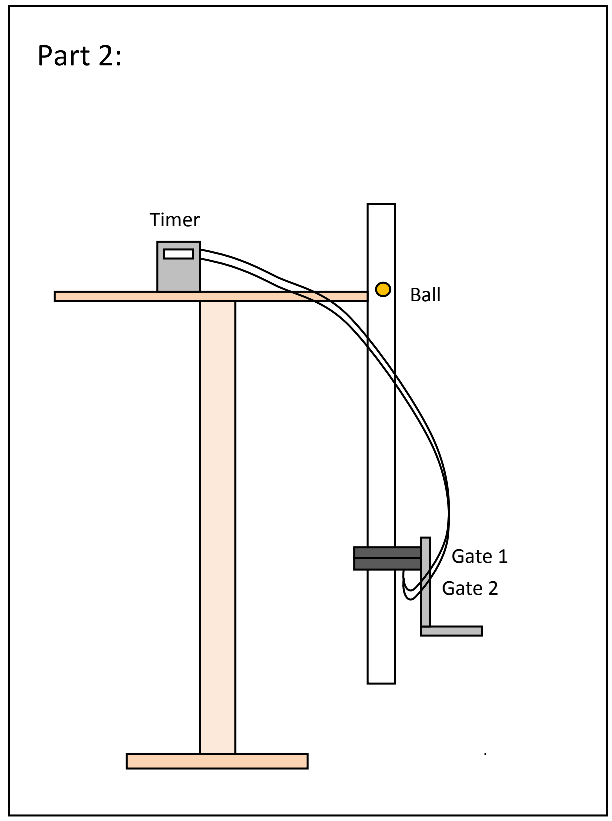
1. The first photo gate was places at the very top of the tube.
2. The second photo gate was placed at increments below.
3. The ball was dropped from rest just above the first gate, three times.

Part 2

1. The two photo gates were zip-tied together.
2. The photo gates were placed at increments below to top of the tube.
3. The ball was dropped from rest just above the top of the tube, three times.

Experimental Setup:

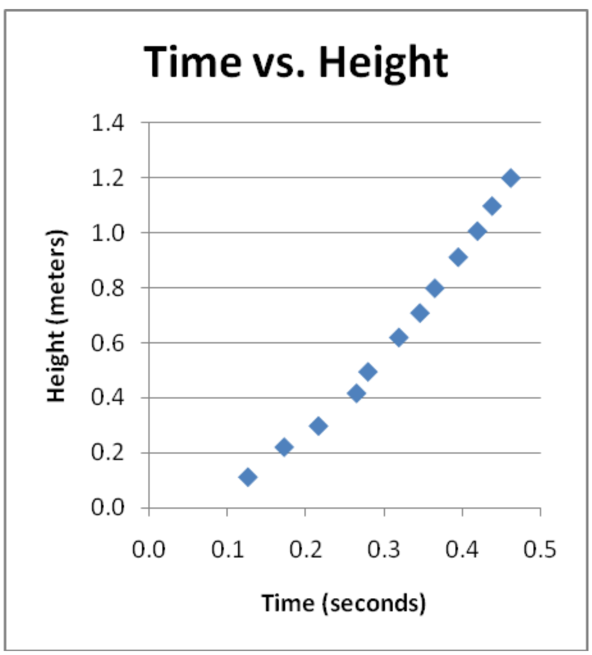


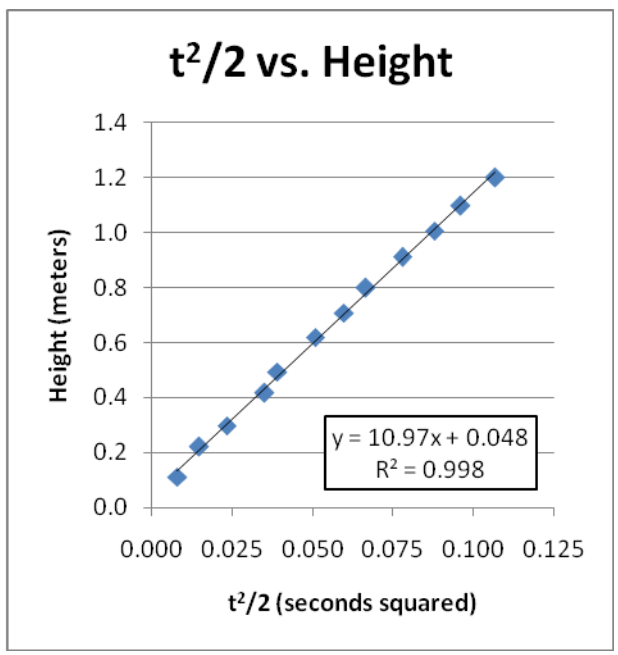


Data/Results – Part 1

Raw Data: **Derived Data:**

Height (cm)	1st Time	2nd Time	3rd Time	Time (average)	$t^2/2$
11.1	0.1228	0.1254	0.1279	0.1254	0.0079
22	0.172	0.1727	0.1704	0.1717	0.0147
29.7	0.2074	0.2232	0.2161	0.2156	0.0232
41.6	0.2693	0.2595	0.2643	0.2644	0.0349
49.4	0.2851	0.2742	0.2777	0.2790	0.0389
61.9	0.3247	0.3142	0.3164	0.3184	0.0507
70.8	0.3445	0.3445	0.3474	0.3455	0.0597
79.8	0.3667	0.364	0.3627	0.3645	0.0664
91.1	0.4022	0.387	0.394	0.3944	0.0778
100.6	0.4146	0.4212	0.4213	0.4190	0.0878
109.7	0.4347	0.4359	0.4428	0.4378	0.0958
119.9	0.4606	0.462	0.4625	0.4617	0.1066



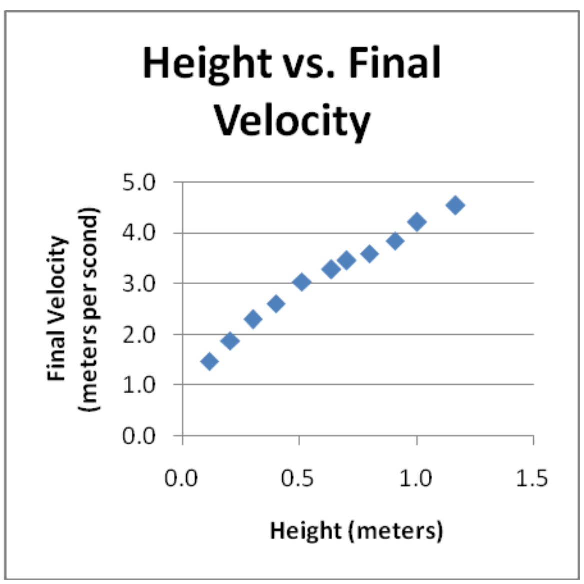


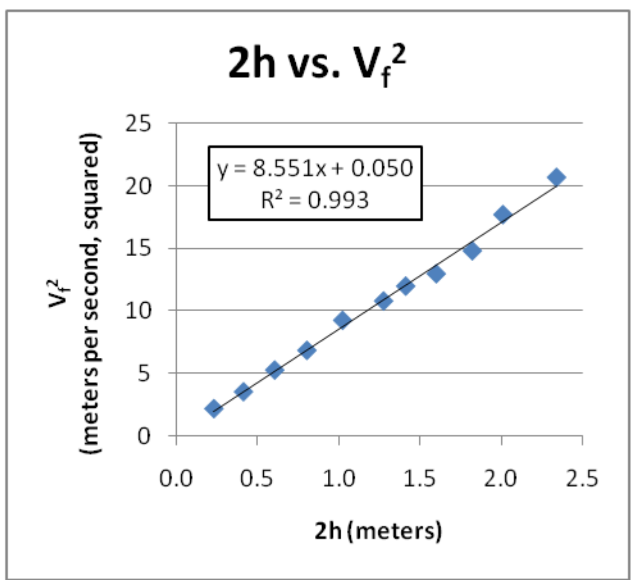
Data/Results – Part 2

Raw Data: **Derived Data:**

Height (cm)	1st Time	2nd Time	3rd Time	Time (average)	Final Velocity *
11.4	0.0098	0.0104	0.0102	0.01013	1.48026
20.5	0.0077	0.0080	0.0082	0.00797	1.88285
30.1	0.0066	0.0065	0.0065	0.00653	2.29592
40	0.0057	0.0057	0.0058	0.00573	2.61628
51	0.0050	0.0050	0.0048	0.00493	3.04054
63.6	0.0046	0.0045	0.0046	0.00457	3.28467
70.4	0.0043	0.0044	0.0043	0.00433	3.46154
79.8	0.0041	0.0042	0.0042	0.00417	3.60000
90.9	0.0039	0.0039	0.0039	0.00390	3.84615
100.3	0.0036	0.0036	0.0035	0.00357	4.20561
116.8	0.0033	0.0033	0.0033	0.00330	4.54545

* Calculated by $\frac{1.5cm}{t_{avg}}$ with 1.5 cm being the distance between the beams of the two gates.





Analysis

Equations:

1. These are the equations that we are using:

   $h = \frac{1}{2}\mathrm{at}^2$ $\qquad$ $v_f^2 = v_0^2 + 2a\Delta x$

2. … which can be rewritten as such:

   $h = g\left(\frac{t^2}{2}\right)$ $\qquad$ $v_f^2 = g(2h) + v_0^2$

3. … to linearize the data and return '*g*' as the slope, in slope-intercept form:

   $y = mx + b$

Theory:

The theory underlying this experiment is that the effects of gravity can be determined by observing objects in freefall, and using standard equations of physics (Equations 1), an approximate value of '*g*' can be calculated.

Interpretation of Results:

The results of the experiment must be interpreted because the raw data doesn't tell us anything useful. This is how we interpreted the data of each part:

Part 1

1. When the raw data is graphed (Time vs. Height) it can be seen that there is a curve along which the data lies. Visually it seems to be parabolic and gives a good feel for the motion of the object.
2. To linearize the data we graphed:

$X = \frac{t^2}{2}$ $Y = h$

3. After fitting a linear model to the second graph (2h vs. V_f^2), it can be seen that the slope (10.97) represents our measurement of '*g*'. The correlation coefficient is .998, indicating that our model is a good fit for the data.

Part 2

1. This part of the experiment observed height and final velocity. When graphed (Height vs. Final Velocity) the data doesn't tell us much.
2. To linearize the data we graphed:

   $X = 2h$ $Y = V_f^2$

3. Fitting a linear model to the second graph (2h vs. V_f^2) yields a slope of 8.55 which represents our measurement of '*g*' for this part. The correlation coefficient is .993, so the second model is almost as good as the first.

Each part gave a good approximate value of '*g*'. When the results from parts one and two are averaged $\left(\frac{10.97+8.55}{2}\right)$ the result is 9.76, which is very close to the expected value of '*g*' (9.8 m/s^2).

Errors:

Systematic

1. Ideally, the y-intercept of our models would be zero. In part one, the y-intercept (.048) indicates that systematically, the ball was probably given more height than recorded. This was likely a result of having to hold the ball above the first beam.
2. The y-intercept of the second model (.050) indicates that systematically, the ball had a little more velocity than it should have. This was, again, likely the result of holding the ball above the top of the tube.

Random

1. The correlation coefficients (.998 and .993) represent the sum of all the random errors. One of the sources of such error is the height from which the ball was dropped (over the starting point), which will vary randomly because of the human element.
2. Another source of random error is the measuring of the height, which is done by using a ruler and includes some human error as well.

Conclusion

This experiment was successful in achieving the stated objective because we came up with a pretty good measurement of *g*.

The experiment was meaningful because it showed that we can observe the properties of gravity and its relationship to time and velocity. Our assumption that velocity increases regularly with constant acceleration is confirmed by the linear relationship show in part two.

The experiment could probably be improved by having longer metal rods (120 cm) so that both gates can be mounted on the same structure, as well as the tube. That would minimize errors created by using books and tables that move.

Applications/Discussion

I did a little reading about the discovery of gravity and its measurement, and I found, of course, Galileo's equation: $s = \frac{1}{2}at^2$

This is the same one which we tested in part one. It seems that Galileo's great leap was to quantify time. Before his discoveries, most scientists used geometry to model falling bodies. I easily see the importance of time in these physical relationships, but it was not so apparent before Mr. Galilei.

I discovered, also, the equation of Newton: $F_g = G\frac{m_1 m_2}{r^2}$

I think that this takes into account the distance between two objects and their masses to calculate the force of gravity (little g). The big G must be the constant force of gravity. Where does this come from? I don't know.

Lastly, I came upon Einstein's equations: $\nabla \cdot T = 0$ and $G = 8\pi T$

I have no idea what these two mean. Maybe that will be explained in the 200 level physics classes.

Objective/Purpose

The purpose of this lab was to measure the individual reaction times of our lab group members.

Equipment/Procedure

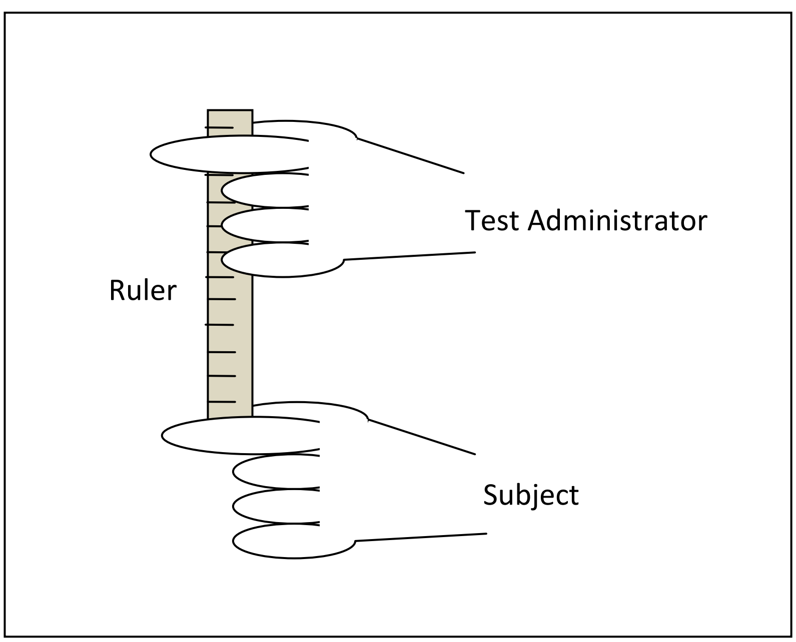
Equipment:

1. Metric Ruler
2. Grasshoppers (x5)

Procedure:

We had each subject sit in a chair with their dominant hand on a table. The ruler was held by another student between the thumb and finger of the subject. When the ruler was dropped, the subject pinched their fingers to stop the ruler, and the distance was measured. This procedure was repeated three times each for each of five subjects.

Experimental Setup:

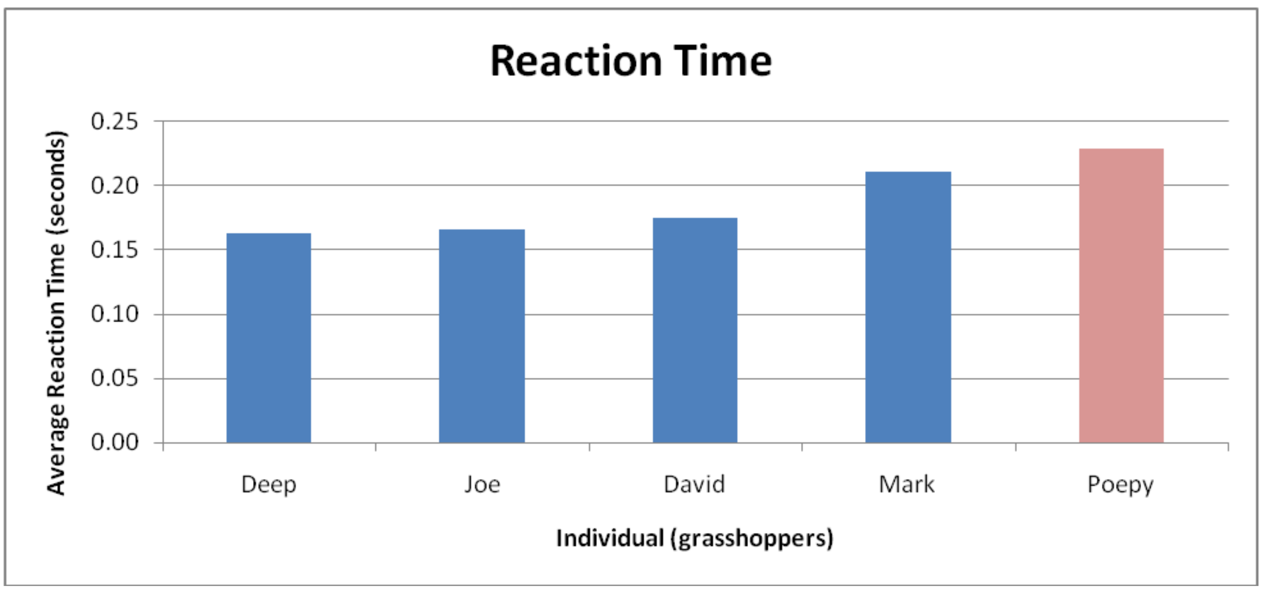


Data/Results

Raw Data: Derived Data:

Person	Gender	h_1 (cm)	h_2	h_3	h_{AVG}	Time *
Deep	Male	13.2	13.3	12.6	13.03	0.1631
Joe	Male	13.5	13.9	13.0	13.47	0.1658
David	Male	12.6	16.5	15.7	14.93	0.1746
Mark	Male	24.5	19.5	21.3	21.77	0.2108
Poepy	Female	26.5	24.6	25.6	25.57	0.2284

* Calculated by $t = \sqrt{\frac{2h}{g}}$



Analysis

Equations:

1. We are using $h = \frac{1}{2}gt^2$ to derive a reaction time from the height.

Theory:

During the time that it takes for an individual to react to the ruler drop, the ruler will accelerate according to Equation 1. Therefore, the reaction time can be derived by dropping the ruler and measuring the distance between the starting point and the final location of the subject's fingers on the ruler. The expected reaction time would be somewhere in the neighborhood of 1/6 – 1/10 of a second.

Interpretation of Results:

The data was sorted by reaction time, from the fastest to the slowest. The blue bars indicate the male subjects and the pink bar indicates the female subject. The average reaction time observed was *.19* seconds, the slowest being *.23* and the fastest *.13*. These results were on the slow end of our expected values, but nothing inhuman.

Although the slowest reaction time belonged to the only female, I don't find any relevant information in this fact. The data can be taken for face value and no other interpretation is required.

Errors:

Systematic

1. There was no requirement to use a particular finger. Some of the subjects used their index finger, some their middle finger, and some changed during the test. The assumption was that the fastest configuration would the one which felt most natural to the subject, but this could be incorrect.
2. Because we had to test all of the members of our lab group, we used two different test administrators. This could have affected the results because each administrator likely had varying degrees of telegraphing (giving foreknowledge of the drop).

3. A longer (and therefore heavier) ruler was needed to accommodate the slower subjects, which tends to slide, biasing the results in the favor of those with a strong finger grip.

Random

1. Each administrator attempted to release at random times, which introduces random errors, such as whether the subject was paying attention at that moment or not.
2. The end of the ruler was placed as close to the middle of the finger and thumb as possible, but the release point likely varied randomly by a couple millimeters vertically due to instability in the administrator's hand.

Conclusion

This experiment was marginally successful. We obtained results which fit within reason, but the systematic and random errors are too great in number and effect to give me confidence in our results. In this way, the results of this experiment are not particularly meaningful to me.

An improvement to the experiment would be to mechanize the releasing process to make the time truly random with no telegraphing. Also, more subjects should be included if male to female comparisons are to be made.

Applications/Discussion

I did some reading on *www.exploratorium.edu/hockey* to find out more about the reaction time of hockey goalies. At 20 feet and 90 mph, a hockey goalie has .152 seconds to react to an incoming puck. None of us would cut it under those circumstances.

One of the most interesting parts of the article was how the players are able to get a puck going over 100 mph using the *slap shot*. It involves storing energy in the stick (by contacting the ice and bowing) and then releasing it into the puck in concert with the swinging of the stick and the player's weight transfer. Over 100 mph …. Wow.