International Baccalaureate

# Extended essay cover

| | | | |
|---|---|---|---|
| *Candidates must complete this page and then give this cover and their final version of the extended essay to their supervisor.* | | | |
| Candidate session number | | | |
| Candidate name | | | |
| School number | | | |
| School name | | | |
| Examination session (May or November) | May | Year | 2013 |

Diploma Programme subject in which this extended essay is registered: Physics

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: The ~~Ef~~ Effects of Spin on the Trajectory of an Object.

**Candidate's declaration**

*This declaration must be signed by the candidate; otherwise a grade may not be issued.*

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Candidate's signature: Date:

## Supervisor's report and declaration

*The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.*

Name of supervisor (CAPITAL letters)

*Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.*

*This declaration must be signed by the supervisor; otherwise a grade may not be issued.*

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent 2 hours with the candidate discussing the progress of the extended essay.

Supervisor's signature: Date:

## Assessment form (for examiner use only)

| Criteria | Achievement level Examiner 1 | maximum | Examiner 2 | maximum | Examiner 3 |
|---|---|---|---|---|---|
| **A** research question | 0 | 2 | | 2 | |
| **B** introduction | 1 | 2 | | 2 | |
| **C** investigation | 2 | 4 | | 4 | |
| **D** knowledge and understanding | 1 | 4 | | 4 | |
| **E** reasoned argument | 1 | 4 | | 4 | |
| **F** analysis and evaluation | 0 | 4 | | 4 | |
| **G** use of subject language | 2 | 4 | | 4 | |
| **H** conclusion | 0 | 2 | | 2 | |
| **I** formal presentation | 2 | 4 | | 4 | |
| **J** abstract | 0 | 2 | | 2 | |
| **K** holistic judgment | 1 | 4 | | 4 | |
| Total out of 36 | 10 | | | | |

# The Effects of Spin on the Trajectory of an Object

Candidate Number:

Physics

12-19-12

Word Count: 2,692

## Abstract

The essay will study as well as explain the effects of spin or circular motion of an object on the trajectory and the ultimate landing of the object. The experiment will provide a explanation of the relationship between the spin (seconds per revolution) and the distance travels from the control from the experiment. In which we had a subject kick one hundred times, with fifty being control kicks and fifty being the experiment kicks. We measured how far away the ball deviated from the straight line where the ball was placed. By determining how far the ball deviated from the straight line we can determine the effect of spin. The control will off course deviate from the straight line even thought it will be kicked with no spin because of the wind gusts and other uncontrollable factors. By comparing the results of the control and experimental kicks we could possibility find some sort of relationship between spin and the motion of the ball. As well as graphing the result in a grid that will show the trajectory of the ball. In addition the research of scientific concepts of the Magnus effect, and the Coanda Effect has provided reasonable explanation for the effects of circular motion on the motion of the object. Such as they reveal that the air flow and the resistance to the air flow depending on the spin causes the object to go off course.

Word Count: 237

# Table of Contents

## 1. Introduction

### 1.1Background Information

In many sports that utilize a circular object for scoring and points, there are many techniques and ways people manipulate the circular object to gain an advantage over the opponent. Mainly, for these sorts of sports they use spin as a way to manipulate the ball. The effect has been noted to be vital in a majority of sports that involves circular objects such as football, basketball, tennis, baseball and many more. The mastery of this concept of spin to a circular object is essential for teams in these sorts of sports because in a way it gives them an advantage over the other teams in their sports. Such as the use of backspin on basketballs to give them a better chance to bounce in and tennis to cause trick the opponent. Finally a spin on a soccer ball can enable a person to make a goal that someone normally can't make with a straight kick. Which makes it sound like spin can have such a profound effect in the movement of the object that it could actually utilized. As well as being reliable and controlled, that it could have a major effect for the outcome of the match. That brings up the statement of whether or not spin has enough of an effect on the trajectory of a circular object that it could reveal the reasoning of such emphasis on the technique.

### 1.2 Objective

This essay is supposed to determine whether or not the spin's effect on the motion of the circular object has a profound effect or a marginal effect. The topic and experiment seems relatively simple because it just involved someone kicking a soccer ball hundred times with the change of technique every 50 kicks to make the ball spin. Then from the videos of the soccer ball, data will be taken from the video about the times; calculations must be made for every single kick to find the rotation of the soccer ball. This will be then compared to control sets and to be determined whether or not the spin actually has a profound effect on the path and landing of the soccer ball. As well as determining if the ball rotates fast would have a different effect than rotating slower.

## 2. Equipment Used

- Two Video Cameras
- A Standard Size 5 Soccer Ball
- A Meter Stick
- Measuring Tape
- Measuring Wheel

Three Color Tape

## 3. Experiment Procedures

1.) Set up the equipment on the blacktop outside or inside with plenty of space, also set up a grid with the help of the measuring tape marking every five meters.

2.) Make sure the two cameras are pointed at the soccer ball at different angles from one side and one from the front, while keeping in view the meter stick to help us read the distance when we plug in the video to some software that slows down the video.

3.) Also make sure to wrap the soccer ball with the different color tape horizontally, vertically, and diagonally. This is to help with determining the rotational speed of the object by marking how fast it makes one full rotation.

4.) The subject will kick the ball 50 times regularly straight without any sort of spin. We will measure the distance travels, mark it on the gird and this is will be the control. As well as how much it deviates from a straight path.

5.) Then the person will kick the ball 50 more times but with a spin we will measure its distance and mark it on the grid and how much it deviates from a straight path.

6.) The subject will not kick the ball in increments of 50, instead it will be kicking in increments of 25 and alternating between control and spin kicks. This is to account for possible changes in wind speed, temperature, and humidity. If it is happening inside, the increments of 25 does not matter and will be based upon the scientist working on the experiment.

7.) Finally we will remove the tape on the blacktop and clean up

## 4. Variables

Here is a variable table for the experiment.

| | Independent Variable | Dependent Variable | Relevant Fixed Variables |
|---|---|---|---|
| Experiment | The Spin of the Object | Distance deviated from the straight line | Wind Speed, Air Temperature, Mass of the Soccer Ball, The kicker |

### 4.1 Controlling Fix Variables

Wind Speed- I just checked the weather services to see the wind gusts and wind speeds for days. I picked two day with the lowest and same wind speeds and gusts. It was vital to keep the wind speed because this has direct relationship with the dependent variable. If the wind speeds was to pick up, the distance deviated by the ball increases. Also I staggered the trials so instead of doing fifty trials of control then fifty trials of spin, I broke it up into four sets of twenty five kick. So I did twenty five kicks of control, then twenty five experimental kicks. Just in case if there was any changes in wind speed.

Air Temperature- The temperature of the air has been known to have effects on objects that contain air in them. To combat this, I spread out the experiment to two days. Also I made sure the experiment started on the same time each day because each passing hour the sun rises or lowers changing the air temperature. The temperature has a direct relationship with the psi in the ball, with an lower outside temperature the ball will have a lower psi or with an high outside temperature there will be a high psi. The psi changes ultimately changes how the ball flies and its trajectory. As well as how the ball reacts when it gets kicked.

Mass of soccer ball- I brought a scale and an air pump to the experiment site. So I would weigh the soccer ball every ten kicks because I know with every kick the psi of the decrease. That in then changes how the ball reacts in the air. Thus we had to keep the same amount of psi in the soccer ball to keep the ball controlled as much as possible.

The kicker- The person kicking the ball is the human component of this experiment, so it is very important that we should control this variable. Such as the power of the kicks from the kicker, if we have the kicker kick with full strength, the data might be very clear, but the kicker won't be able to keep that same power for one hundred kicks. So I had him kick with moderate to week power because I wanted to have every kick constant so we could compare the data equally. Also that is why I had the experiment last two days because kicking a ball one hundred times can be tiring. Also before each day we had two practice kick, so from the first day's practice kick's distances so we tried to match up to those practice kick's so we could obtain the same amount of power for both days.

## 5. Research

There are multiple things affecting the flight of the ball, from the wind pushing it or just the temperature outside effecting how the ball reacts while in the air. Especially let us focus on the effects that involve spin because the other affects should have had controlled because the effects would be the same for the two different sets of data were taken in the same environment and conditions. The effects affecting the trajectory related to spin would be the drag, Coanda Effect, and the Magnus Effect.

The balls used in sports aren't perfectly round balls; there is always some sort of imperfection which causes drag in the ball. For example the stitches in a baseball or there is not enough air in the soccer ball to make it into a perfect sphere. By having the object rotate more, it allows the imperfection to have more of an effect on the flight of the object. Also we can see how much the surface of the ball matters in determining the drag[1]. Thus a rapidly rotating ball will have more drag than a slower rotating ball so the ball should slow down less. But actually the increase in drag caused by spin does slow the ball down but not enough to have a major effective[2].

The Coanda effect explains the air's tendency to follow the surface of the object, but when spin is introduced it causes one side to be accelerating faster than the other side. That ultimately causes the ball to curve more toward the side with the lowest acceleration. For

[1] Look at figure 1 in the appendix provided by Adair, Robert K; notice how the differences in the drag coefficient between how spin affects different types of surfaces, rough and smooth.

[2] Adair, Robert K did an experiment similar to mine, but used baseball instead of a soccer ball. He noticed that the drag created by the spin only affected the ball in a minor way, saying that across home plate it only slowed down the ball by .2 meters per second.

example, if side A was going with the air then the acceleration will be higher than side B that would be going against the air. Thus the ball will curve more towards side B.

The Magnus effect, founded by Gustav Magnus, noted for its tremendous lift force has the ability to alter and curve the path of a ball. It can be applied to any circular object that could be kicked or thrown as long as it has a given spin. The Magnus effect is just a forced caused by an imbalance of the drag forces. There is an imbalance because one side of the ball is colliding with the air causes there to be a deceleration on that side, thus creating an area of high pressure. While the other side is going in the same direction with the air so it doesn't decelerated. The difference in pressures causes the ball to be affected by another force that flows from the high pressure to the low pressure[3]. The force is perpendicular to the direction of motion. There is no restriction on where the resulting force can be pointed at, it could provide it lift by the resulting force pointed upwards or down, or left to right. Unlike drag, this does have a major effect because during the 2010 FIFA World Cup, there were complaints by the players about how the match ball was different from a regular soccer ball. They were able to notice how the ball did not fly regularly when they kicked it with a spin. The players were correct because the shape of the ball was actually slightly altered and the players were to tell the slight alteration.

## 6. Data Analysis

I took the data from the experiment and looked at the deviations for the control and the experiment and took their averages. There seems to be a correlation between the spin and the amount of distance deviated. First off is it is clear that the difference between kicking it with spin

[3] Look at figure 2 also provided by Adair, Robert K; displaying the diagram of the Magnus effect when comparing between a non-spinning ball and a spinning ball.

than kicking it without spin because the meters the ball deviated from a straight path between the two had a substantial difference. The average deviation for no spin was 1.38 meters and the average deviation for spin was 6 meters, so they had a difference of 4.52 meters[4]. So it is clear that there is an increase in deviations as the ball rotates quicker.

Let's look at the spin date itself. When I plotted the data with the spin, measured in seconds per revolution, against amount deviated, there appears to be some sort of negative relationship because as the ball rotated faster the amount deviated increased[5]. Though the data might be scattered slightly, the overall pattern is that the more time it takes to complete a revolution the ball will deviate and curve less.

## 7. Possible Errors and Uncertainty

With any experiment, there will be error. Though the error might be difficult to constrain because there will be forces that I cannot control such as temperature, pressure, and wind. I will try to constrain by trying to have the experiment take place indoors, or outside during a calm day. I would have wanted to do the experiment indoors because then I would have had direct control over the factors like temperature, pressure, and wind. But due to gym policy they wouldn't let just a student privately rent out a space for a couple hours. In addition, I didn't want any sort of interference whiling running my experiment so I decided on doing the experiment outside. As well as I try to alternate between sets of controls and sets of the actual experiment so if there is actually any changes the changes will affect both sets and not just one.

---

[4] Reference to figure 3, the data table from the experiment and the average is at the bottom of the table. Notice the major difference in the averages

[5] Reference to figure 5, the displayed data of spin against the amount deviated. Please note, the relative negative relationship that as the spin rate slows down the less the ball deviates.

In addition, since I am using a human subject to kick there will be the human error because there is no way he is able to kick the soccer ball with the same power and speed. As well as he can't kick the soccer ball at the same angle but hopefully since we have fifty soccer kicks that will be enough to make a stable data set. Also for the measurements for the revolutions per second for the soccer ball might be a bit off since I will be using loggerpro. Though it allows me to slow down the video, it only allows me to slow it down to sections so sometimes I might over shoot or under shoot the full rotation. Thus I will be giving the an error of +/- or .003 seconds for the revolutions

## 8. Conclusion

There is a moderate relationship between spin and the curve of the ball, as the rate of spin increases the more the ball deviates. Hopefully the next time you kick a soccer ball or hit a tennis ball you will see that there are things at work other than air resistance and force. That you see that you actually have more control over the object than you knew before and that with practice you can refine and master it. This concept doesn't have to necessary be applied to only sports.

Appendix

Figure 1

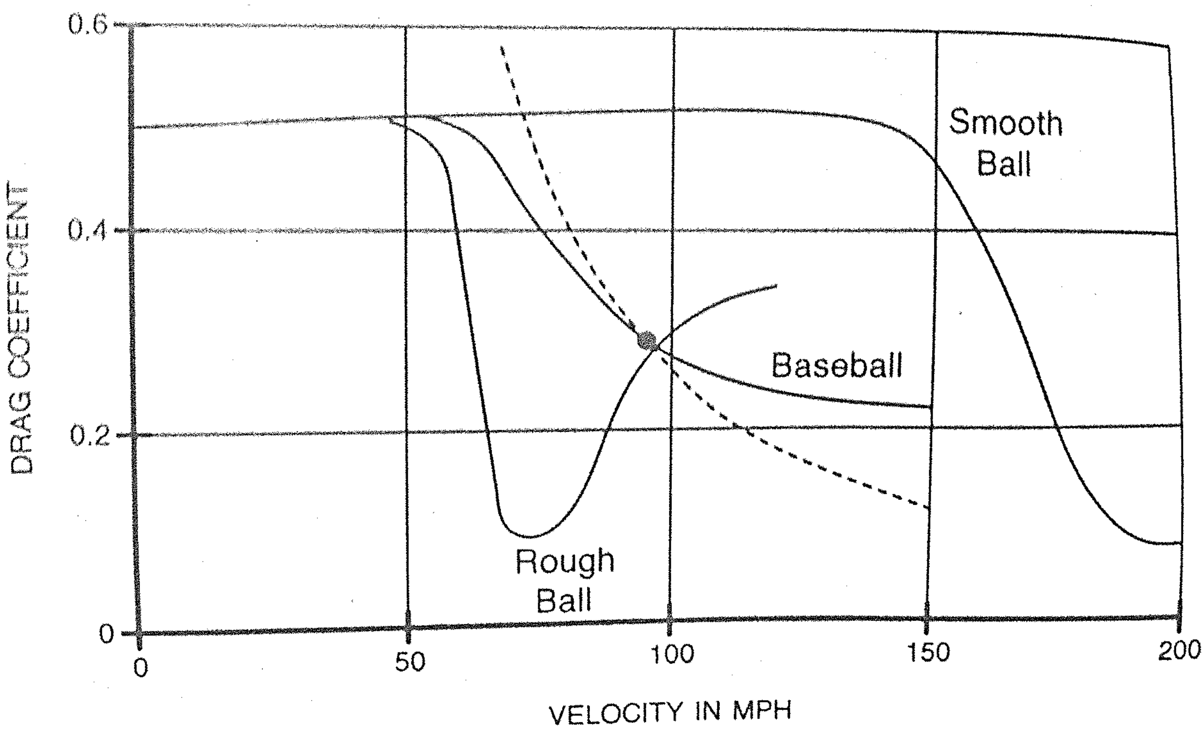



Figure 2

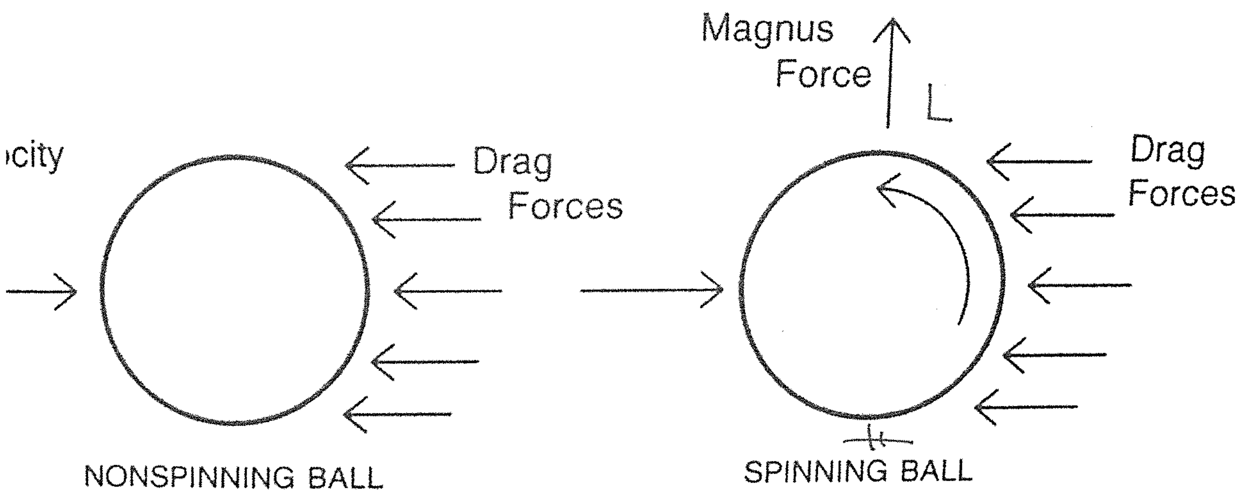


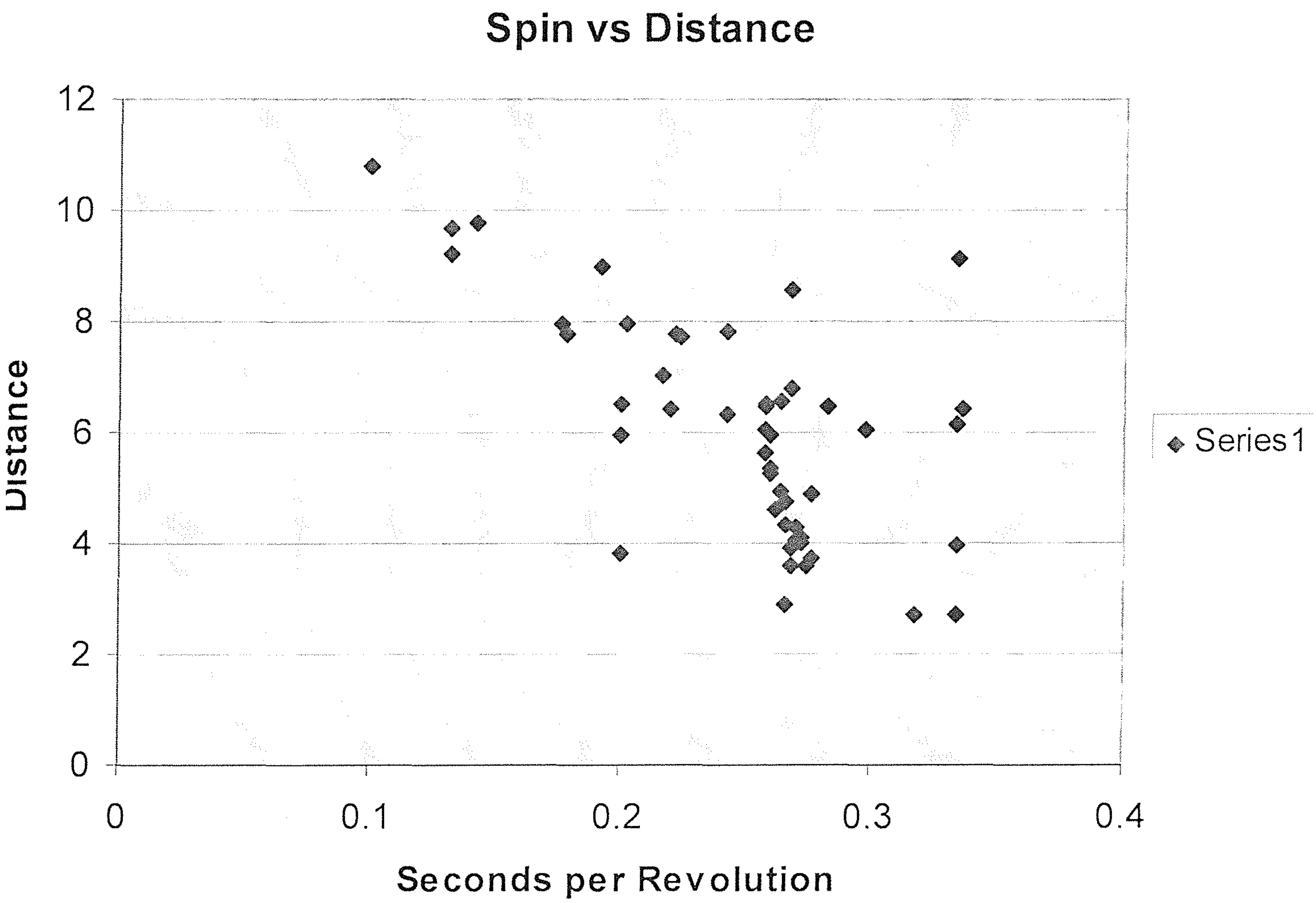
Figure 3

Figure 4

| | Control (meters) +/- .3 | Experiment (meters) +/- .3 |
|---|---|---|
| 1 | 1.55 | 5.33 |
| 2 | 1.28 | 4.27 |
| 3 | 1.68 | 6.43 |
| 4 | 0.52 | 6.51 |
| 5 | 1.41 | 6.34 |
| 6 | 0.5 | 4.02 |
| 7 | 2.45 | 6.05 |
| 8 | 2.85 | 7.75 |
| 9 | 0.33 | 7.98 |
| 10 | 0.34 | 9.78 |
| 11 | 1.08 | 4.75 |
| 12 | 0.47 | 6.51 |
| 13 | 0.53 | 6.05 |
| 14 | 0.58 | 2.72 |
| 15 | 1.69 | 7.73 |
| 16 | 1.78 | 4.05 |
| 17 | 2.74 | 7.78 |
| 18 | 0.54 | 8.98 |
| 19 | 1.28 | 5.35 |
| 20 | 1 | 7.95 |
| 21 | 1.62 | 9.21 |
| 22 | 2.51 | 5.62 |
| 23 | 0.08 | 3.56 |
| 24 | 2.87 | 7 |
| 25 | 1.71 | 4.95 |
| 26 | 0.38 | 5.98 |
| 27 | 3.61 | 6.13 |
| 28 | 0.38 | 6.43 |
| 29 | 4.42 | 3.94 |
| 30 | 1.51 | 8.54 |
| 31 | 1.68 | 6.8 |
| 32 | 0.97 | 9.7 |
| 33 | 1.99 | 3.8 |
| 34 | 0.29 | 6.56 |
| 35 | 0.53 | 3.9 |
| 36 | 3.18 | 4.34 |
| 37 | 1.41 | 2.9 |
| 38 | 1.73 | 9.09 |
| 39 | 3.2 | 4.01 |
| 40 | 2.01 | 4.11 |
| 41 | 1.84 | 6.46 |
| 42 | 0.41 | 4.9 |
| 43 | 1.02 | 10.81 |
| 44 | 1.93 | 3.6 |
| 45 | 0.41 | 7.81 |
| 46 | 0.77 | 2.72 |
| 47 | 1.04 | 6.46 |
| 48 | 0.08 | 4.6 |
| 49 | 0.03 | 5.27 |
| 50 | 0.74 | 3.72 |
| e Deviation | 1.38 | 6 |

| Trials | Experiment (meters) +/- .3 | Spin (Sec per Rev) |
|---|---|---|
| 1 | 5.93 | 0.26 |
| 2 | 4.27 | 0.27 |
| 3 | 6.43 | 0.22 |
| 4 | 6.51 | 0.2 |
| 5 | 6.34 | 0.24 |
| 6 | 4.02 | 0.27 |
| 7 | 6.05 | 0.3 |
| 8 | 7.75 | 0.18 |
| 9 | 7.98 | 0.18 |
| 10 | 9.78 | 0.14 |
| 11 | 4.75 | 0.27 |
| 12 | 6.51 | 0.26 |
| 13 | 6.05 | 0.26 |
| 14 | 2.72 | 0.32 |
| 15 | 7.73 | 0.22 |
| 16 | 4.05 | 0.27 |
| 17 | 7.78 | 0.22 |
| 18 | 8.98 | 0.19 |
| 19 | 5.35 | 0.26 |
| 20 | 7.95 | 0.2 |
| 21 | 9.21 | 0.13 |
| 22 | 5.62 | 0.26 |
| 23 | 3.56 | 0.27 |
| 24 | 7 | 0.22 |
| 25 | 4.95 | 0.26 |
| 26 | 5.98 | 0.2 |
| 27 | 6.13 | 0.33 |
| 28 | 6.43 | 0.34 |
| 29 | 3.94 | 0.33 |
| 30 | 8.54 | 0.27 |
| 31 | 6.8 | 0.27 |
| 32 | 9.7 | 0.13 |
| 33 | 3.8 | 0.2 |
| 34 | 6.56 | 0.26 |
| 35 | 3.9 | 0.27 |
| 36 | 4.34 | 0.27 |
| 37 | 2.9 | 0.27 |
| 38 | 9.09 | 0.33 |
| 39 | 4.01 | 0.27 |
| 40 | 4.11 | 0.27 |
| 41 | 6.46 | 0.28 |
| 42 | 4.9 | 0.28 |
| 43 | 10.81 | 0.1 |
| 44 | 3.6 | 0.27 |
| 45 | 7.81 | 0.24 |
| 46 | 2.72 | 0.33 |
| 47 | 6.46 | 0.26 |
| 48 | 4.6 | 0.26 |
| 49 | 5.27 | 0.26 |
| 50 | 3.72 | 0.28 |

Figure 5



Spin vs Distance
12
10
8
6
4
2
0
Distance
0
0.1
0.2
0.3
0.4
Seconds per Revolution
Series1

## 10. Biblography

Adair, Robert K. "The Physics of Baseball." New York: Harper & Row Publisher, 1990. Print

Carré, Matt, and John Eric Goff. "Researchers Investigate Spin of World Cup Football."*Sheffield.* The University of Sheffield, 17 June 2012. Web. 28 Apr. 2012. <http://www.sheffield.ac.uk/mediacentre/2010/1665.html>.

Colon, Terry. "Bernoulli, Coanda & Lift." *Bernoulli, Coanda & Lift.* Terrycolon, 2007. Web. 29 May 2012. <http://www.terrycolon.com/1features/ber.html>.

Cutnell, John D., and Kenneth W. Johnson. *Physics.* Fourth ed. New York: John Wiley & Sons, 1998. Print.

Goff, John Eric, and Matt J Carre. "Trajectory analysis of a soccer ball." Trajectory analysis of a soccer ball. Lynchburg: American Association of Physics Teachers, 2009. 1020-1027. Goff-j.web.lynchburg. Web. 27 Apr. 2012. <http://goff-j.web.lynchburg.edu/Goff_Carre_AJP_2009.pdf>.

Human Kinetics. "Magnus Effect." *Humankinetics.* Human Kinetics, 2012. Web. 28 Apr. 2012. < http://www.humankinetics.com/excerpts/excerpts/magnus-effect->.

Raskin, Jef. "Coanda Effect Understanding Why Wings Work." *Jef Raskin - Coanda Effect: Understanding Why Wings Work.* Karmak, 1994. Web. 29 May 2012. <http://karmak.org/archive/2003/02/coanda_effect.html>.