# http://www.anglochineseprimary.net/2012/WEB/INDEX/images/ACS-CREST-OFFICIAL%20copy_New11-2.jpg

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# 5.03 Leviticus

# Group 4 Project

# Research Question: Investigating the relationship between the concentration of corn starch in water and the time taken for a marble to sink through a column of said mixture

Introduction

The aim of this experiment was to investigate and extrapolate a possible relationship between the concentration of corn starch within oobleck (a mixture of corn starch and pure water), and the time taken for a marble to fall through a column of oobleck.

We hypothesized that as more corn starch was added to water, the longer time it would take to fall through the column – and would be related by a linear relationship. This is because we had theorised that as more corn starch was added, the bigger the concentration of bigger molecules (i.e. corn starch molecules as compared to normal water molecules) would be within the mixture, the more viscous the mixture is, and thus, the more difficult it is for the marble to sink through.

The variables of the experiment are detailed as followed:

**INDEPENDENT**: concentration of corn starch in the oobleck  
**DEPENDENT**: Sinking time of the marble through the column  
**CONTROLLED**: marble used, length of oobleck column, type of glass rod, measuring cylinder, weighing container and weighing scale used, type of corn starch, temperature of environment



Background Information

The mixture in question – the oobleck – works in a very peculiar way. This is because it is a Non-Newtonian fluid, meaning that the fluids do not follow the simple Newtonian laws of individual liquids – i.e. they should flow at a consistent rate granted no net force should be acting upon it when flowing.

While oobleck is technically a liquid – or a suspension of corn starch molecules in water, since the corn starch does not dissolve – it acts like a solid when force is applied to it, which explains why, when we punched it, it seemed to act like a solid, and with repeated punching, our fists never plunged below the surface.

The reason why these solid-like features are showcased in oobleck is due to its molecular-makeup – which consists of the grains of corn starch and water molecules. With force being applied, the water molecules either seep into the holes between corn starch molecules, which leads to the mixture “locking up” and holding its shape, or get pushed away from the site of impact . The grains of corn starch would then pile up to the surface where it meets the applied force and then act like a super-compressed, solid-like substance.

With such background information in mind, it is easy to see that, with more corn starch added, the viscosity of the mixture increases. Thus we decided to explore this growth in viscosity and its ability to deter the sinking of an object through a column of said mixture.

Apparatus used and Set-Up

Weighing container

Marble

Mixing container #2

Column of oobleck (250cm3)

Bowl of corn starch

Mixing Container #1

Weighing scale

Measuring cylinder\*

**\*The measuring cylinder was where the main bulk of our experiment transpired in**

Spoon

Glass rod

Experimental Procedure

1. First, fill the measuring cylinder with water up to the 250cm3 mark. The shape of the cylinder made it rather difficult to measure its height, which led us to estimate its height at 20 cm.
2. The marble was placed at the surface of the water before being released. The time taken for it to reach the bottom was recorded. This process was repeated three times in order to reduce trial and error.
3. The water was poured into Mixing Container #1, where the marble is retrieved.
4. 50g of corn starch was then weighed using the weighing container and scale. This was then added into the mixing container and stirred with the glass rod. The concentration of corn starch here would be 50g/250cm3, or 0.20g/cm3.
5. The cylinder is filled up to the same 250cm3 mark with the mixture, and the marble is dropped again, its time taken to reach the base recorded. This process was repeated three times in order to reduce trial and error.
6. Repeat Step 3-5 as necessary.

**Note:**

While in theory, this procedure should go on into infinity – unfortunately, there would come a point where, as we realised, it got more difficult to ensure the corn starch remained suspended.

This came to a point where, at the 5th increment (i.e. with 250g of corn starch added), the mixture had to be poured into Container #2 in order to mix the oobleck with our bare hands.

Despite this, we had to make a change to Step 4 on the 7th increment (i.e. with 350g of corn starch added) such that the subsequent increments would be of 10g of corn starch instead. Due to time constraint and increasing difficulty to suspend the corn starch, we stopped after 7 increments following the first 7th increment (i.e. with 420g of corn starch added).

With the first 7 increments came increments of concentration of 0.20g/cm3, and with the last 7 increments came increments of concentration of 0.040g/cm3.

Data Collected and Processed

Before the data can be represented, justification has to be given regarding the values recorded – i.e. for the two variables of the mass of corn starch weighed, the time taken for the marble to sink, as well as the volume of oobleck.

**Table 1: Table of Justification**

|  |  |
| --- | --- |
| Value + Uncertainty | Justification |
| Mass of Corn starch in mixture (± 0.2n)g[[1]](#footnote-1) | As detailed later, the uncertainty of the weighing scale – 0.1g – is doubled, as it is taken by subtracting a final value of a container with its starch and the initial value of merely the container, to give an initial uncertainty of 0.2g on its first increment. With its next increment the mass of corn starch added compounds with another 50 or 10g, and is thus why with every increment, the uncertainty increases by another 0.2g. |
| Time taken (±0.2s) | This is a rough estimate of the human reaction time and the stopwatch uncertainty combined associated with the time recorded, to 1 significant figure. |
| Volume of oobleck used (±5cm3) | This uncertainty was read off straight off from the uncertainty stated on the measuring cylinder given. |

The data that we collected can be represented as below:

**Table 2: Table of Weighed corn starch added**

|  |  |
| --- | --- |
| Item | Mass /g |
| Weighing Container (± 0.1g) | 114.8 |
| Weighing Container and corn starch (± 0.1g) | 164.8 or 124.8[[2]](#footnote-2) |
| Corn starch (± 0.2g) | 50.0 or 10.0 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Nth increment | Mass of corn starch added | Time taken (±0.2s) | | |
| 0 | 0.0 | 0.6 | 0.5 | 0.7 |
| 1 | 50.0 (± 0.2g) | 0.9 | 0.8 | 0.8 |
| 2 | 100.0 (± 0.4g) | 0.9 | 0.8 | 0.9 |
| 3 | 150.0 (± 0.6g) | 0.9 | 0.9 | 0.9 |
| 4 | 200.0 (± 0.8g) | 0.7 | 0.8 | 0.7 |
| 5 | 250 (± 1g)[[3]](#footnote-3) | 0.8 | 0.9 | 1.0 |
| 6 | 300 (± 1g) | 1.2 | 1.2 | 1.2 |
| 7 | 350 (± 1g) | 2.4 | 2.2 | 2.4 |
| 8 | 360 (± 2g) | 3.0 | 2.5 | 2.5 |
| 9 | 370(± 2g) | 2.3 | 2.4 | 2.5 |
| 10 | 380 (± 2g) | 3.4 | 3.3 | 3.1 |
| 11 | 390 (± 2g) | 4.4 | 4.0 | 4.2 |
| 12 | 400 (± 2g) | 6.0 | 6.5 | 6.6 |
| 13 | 410 (± 3g) | 10.0 | 12.5 | 14.3 |
| 14 | 420 (± 3g) | 22.5 | 30.3 | 31.3 |

**Table 3: Table of Collected Data**

**Table 4: Table of Processed Data**

|  |  |  |  |
| --- | --- | --- | --- |
| Nth increment | Concentration of corn starch in oobleck /gcm-3 | Uncertainty of concentration  /gcm-3 | Average time taken (±0.2s) |
| 0 | 0 | 0 | 0.6 |
| 1 | 0.200 | 0.005 | 0.8 |
| 2 | 0.40 | 0.01 | 0.9 |
| 3 | 0.60 | 0.01 | 0.9 |
| 4 | 0.80 | 0.02 | 0.7 |
| 5 | 1.00 | 0.02 | 0.9 |
| 6 | 1.20 | 0.03 | 1.2 |
| 7 | 1.40 | 0.03 | 2.3 |
| 8 | 1.44 | 0.04 | 2.6 |
| 9 | 1.48 | 0.04 | 2.4 |
| 10 | 1.52 | 0.04 | 3.3 |
| 11 | 1.56 | 0.04 | 4.2 |
| 12 | 1.60 | 0.04 | 6.4 |
| 13 | 1.64 | 0.04 | 12.3 |
| 14 | 1.68 | 0.04 | 28.0 |

**List of calculations made**

* Uncertainty of mass corn starch added

(See Table 1: Justification of uncertainties)

* Average time taken
* Concentration of corn starch in oobleck

Similarly, from the 8th increment onwards, a trend can be observed in that the mass now gets represented as:

As can be observed from Table 3, the mass of corn starch added for the 0th to 7th increment can be expressed as:

Evaluation of Obtained Results

As can be seen from the graph plotted, the results of our experiment had been different than what we expected. This was mainly due to the physics involved in the making of the oobleck – and the non-Newtonian features that evolve with the addition of more and more corn starch in the oobleck. The way our group had initially theorized proved to be wrong – where we assumed that the presence of corn starch would linearly affect the marble’s sinking process’s time – since more molecules would equally mean more hindrance for sinking and thus more time.

The reason why the graph appears to be linear at first is that the presence of corn starch molecules does not significantly affect the sinking at first, as the rate of which the molecules in the mixture making way for the marble to sink would roughly be the same.

At roughly 1g/cm3 however, it can be speculated that at this point, the non-Newtonian nature of oobleck begins to be more conspicuous. This thus takes form in a more substantial hindrance in that the marble begins to sink, and encounters “sheets” of molecules that becomes increasing more difficult to overcome with the inclusion of more corn starch in the mixture. The force of gravity enacting on the marble against this “sheet” or layer of oobleck is met with a dense substance of packed corn starch and water acting more solidly against it.

While we cannot prove mathematically or formulaically that such an exponential relation exists, we can conclude that before the concentration of corn starch reaches 1g/cm3, the molecular makeup of the mixture does not change drastically to the point where the molecules can pile up and compact on the presence of force.

From 1g/cm3, the relationship can be extrapolated to be an exponential growth – of what power is yet to be actually be scientifically proven or calculated – but it would be at this point where there is a sufficient concentration of corn starch molecules for this packing of “sheets” to transpire within the oobleck. With more corn starch comes an accelerated increase of the sinking time for the marble.

Limitations

There were several limitations that came attached to our project due to lack of available materials to us and the lack of time. Due to the lack of prior knowledge in this aspect, we were unable to pre-empt what would be the trend of our curve, which thus explains why we do not a substantial derived equation for this relationship. Because of this lack of prior knowledge, the distances between our points from 1g/cm3 onwards turned out much bigger than expected, which could have led to inherent inaccuracies within it – should we have been more informed before conducting the experiment, we would have known what to expect and thus reduced this magnitude of the appearance of random errors.

In addition, our method of mixing the oobleck –especially with our bare hands- came ridden with problems. While this was the only way to properly dissolve the corn starch in the mixture in the duration of our experiment, this would have led to many inaccuracies such as contamination from our hands and some of the mixture getting stuck to our hands. Putting it in the mixing containers would have led to inaccurate reading s as well due to the sheer fact that the surface area of our second mixing container proved to be big – and laying it to rest for too long would result in some water evaporated and thus distorting the actual value of the oobleck’s corn starch concentration. Thus with better equipment and perhaps if we had done the experiment slightly faster, we could have reduced these sources of random and systematic errors respectively.

The process of recording the time also proved extremely inaccurate as well – not only due to the inconsistency of human reaction time leading to much deviation in the first few increments of corn starch in the oobleck, but in the column as well. Oobleck is a suspension – i.e. the corn starch is merely floating around in the water - and with the passing of time, these molecules would have sunk to the bottom of the column. This would distort our results unpredictably, as at first the marble would easily pass through the oobleck, the difficulty level increasing over time until it would be nearly impossible for it to hit the bottom left to gravity. Thus, having a device to possibly shake the column and even out the concentration of corn starch, and possibly quickening the pace of which this experiment was conducted, would lead to far more accurate results with the reduction of such random errors.

1. “n” being the number of increments having already added into the corn starch, including the value the uncertainty is married to. [↑](#footnote-ref-1)
2. The former value corresponding to the first 7 increments, and the latter corresponding to the last 7. [↑](#footnote-ref-2)
3. The uncertainties are rounded off to only 1 significant figure each. [↑](#footnote-ref-3)