SOnerd's Experimental Design Tips, Tests, and Sample Write-Up

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SOnerd's Experimental Design Tips

General Tips:

- Make sure you can work well with your partners. You do not necessarily have to get along well with them outside of competition, but you need to be able to put aside your differences for 50 minutes to write a killer Exp Des write-up.
- You are allowed to bring a **ruler/meter stick**, **timer/stopwatch**, and **calculator**. Before the competition, communicate with your partners to make sure that you'll have all of the allowed objects. Also, bring **graph paper**. It is not always provided, and having it will make the graph section much easier and neater.
- Don't forget your goggles!
- **Memorize the rubric**. Sometimes, proctors will not allow you to use the rubric during the test, and having it memorized will put you at a distinct advantage over other teams.
  - If you are struggling to memorize it all or are pressed for time, split up sections with your partners, designating each person a specific amount to memorize. You should try to have each person memorize what they will be doing during the test. However, each person memorizing the whole rubric is ideal.
  - Use your knowledge of the rubric to your advantage during the test. When I'm doing my writing sections (see below), I always go based strictly upon what is in the rubric, and I highlight "buzzwords" from the rubric in my sections. This helps the graders know that you understand the rubric, and it makes it very easy for them to find places to give you points. See the sample write-up for a demonstration of this highlighting.
  - The most important thing you can doing during Experimental Design is **follow the rubric exactly**. Teams are ranked based on how many rubric points they score, not how complicated or insightful their experiment is. In order to do well, you MUST pay attention to the **specific details under each section of the rubric**.
- If you are not already given an outline and have to use your own paper, try your best to keep everything in the correct order. This will make the graders' job much easier.
- Write as neatly as possible. Although neatness is not specifically graded, many proctors will break ties based on neatness.
- Do NOT waste a bunch of time thinking of a creative experiment. The graders grade you based *only* upon the rubric, not how insightful your experiment is. As long as it is on-topic, don't worry about how "unique" or "creative" is. You should focus your effort on creating a great write-up.
- **Practice** with your teammates at least once before the competition. This can be as simple as going over to somebody's house and having a third party get together a few materials, then doing the experiment and write-up and a timed environment. Practicing will give you a good idea of how the timing will work out, which will help you work more efficiently during the competition.

Dividing the Work

- Allot the different tasks based on your teammates' strengths. For example, I am the best writer in my group, so I try to take as many of the writing sections as I can. Our strongest math person is designated to run the experiment and do statistics, while the last person helps where needed (usually with the writing stuff that I can't finish in time). Usually, the division of labor during tests goes something like this: (orange = me; red = experiment and stats person; green = misc person)

A) Statement of Problem (4 points)
B) Hypothesis (8 points)
C) Variables
  a. Independent Variable (6 points)
  b. Dependent Variable (6 points)
  c. Control Variables (8 points)
D) Standard of Comparison (4 points)
E) Materials (6 points)
F) Procedure (12 points)
G) Qualitative Observations (8 points)
H) Quantitative Data- Data Table (12 points)
  a. Running the Experiment (also green)
I) Graphs (10 points)
J) Statistics (6 points)
K) Analysis/Interpretation of Data (8 points)
L) Possible Experimental Errors (6 points)
M) Conclusion (8 points)
N) Applications and Recommendations for Further Use (8 points)

Time Management/Order

- This is a very important lesson that I finally learned after 2 years of doing Experimental Design: When you're deciding in what order to do the sections, you MUST take into consideration which sections are "**data-dependent**", or for which ones you need to see the data to be able to do them properly. Here's a rough outline of the rubric with the **data-dependent** and **data-independent** sections indicated:

A) Statement of Problem (4 points)
B) Hypothesis (8 points)
C) Variables
 a. Independent Variable (6 points)
 b. Dependent Variable (6 points)
 c. Control Variables (8 points)
D) Standard of Comparison (4 points)
E) Materials (6 points)
F) Procedure (12 points)
G) Qualitative Observations (8 points)
H) Quantitative Data- Data Table (12 points)
I) Graphs (10 points)
J) Statistics (6 points)
K) Analysis/Interpretation of Data (8 points)
L) Possible Experimental Errors (6 points)
M) Conclusion (8 points)
N) Applications and Recommendations for Further Use (8 points)

You should plan the order so that your writer does the **data-independent** sections first, and then moves on to the **data-dependent** sections after the experiment is over. (In other words- you can't write sections such as the **qualitative observations** without the data, so don't have your writer waste time waiting for the experiment to be finished. Instead, they should skip to another section (any of the **black, bolded sections**)).

- For example, with my partners, the order usually goes something like this:

1. We think of our experiment quickly, making sure it relates to the topic. This should take less than 5 minutes.
2. Red person immediately starts setting up the experiment while green person starts making the outlines of the **data tables** and **graphs**. Orange person (me) starts writing the **statement of problem** and **hypothesis**.
3. When the green person finishes preparing the places for data recording, they begin **variables** and **SOC** while I continue working my way through **materials** and **procedure**. Red person is running the experiment during this time.
4. If the experiment is not yet finished, the green person skips straight to **Applications and Recommendations for Further Use**.
5. Red person finishes up the experiment, **Quantitative Data**, **Graph**, and **Stats**, and I begin work on the **Qualitative Observations** and **Analysis/Interpretation of Data**.
6. Whoever is free works on **Possible Experimental Errors** and/or **Conclusion**.
7. If we have time left after finishing, we go back through and check each other's work to make sure that it has all the components required in the rubric.

- Remember that although it's important to have a plan going into the test, you don't have to follow it exactly. The exact amount of time stuff takes to finish will be slightly different every time, so you have to be willing to be flexible and possibly do sections that aren't yours.

Test 1 (including sample write-up)

Topic: Oil Spill Cleanup

Background: With the increase of petroleum exploitation in the ocean, oil spills ("The leakage of petroleum onto the surface of a large body of water" (Source: Encyclopedia Britannica)) are becoming a growing problem. Your task today is to use the materials given to design an experiment that will determine the most efficient way to clean up spilled "oil" that has been washed up on the beach.

You will be given all of the following materials: (you do not have to use all of them)

- Scale
- Teaspoon
- ¼ cup of Canola cooking oil (to avoid making a mess, water can be substituted for this)
- Paper plate
- Plastic spoon
- 1 sheet of printer paper
- 1 Bounty paper towel
- 1 sheet of cardstock
- 1, 5cm by 5cm piece of newspaper
- Tweezers
- Dishrag
- Scissors

If you brought the following materials, you may use them:

- Stopwatch
- Ruler/Protractor

Remember, your write-up must contain all of the following elements:

- **Statement of Problem (4 points)**
- **Hypothesis (8 points)**
- **Variables**
    - **Independent Variable (6 points)**
    - **Dependent Variable (6 points)**
    - **Control Variables (8 points)**
- **Standard of Comparison (4 points)**
- **Materials (6 points)**
- **Procedure (12 points)**
- **Qualitative Observations (8 points)**
- **Quantitative Data- Data Table (12 points)**
- **Graphs (10 points)**
- **Statistics (6 points)**
- **Analysis/Interpretation of Data (8 points)**
- **Possible Experimental Errors (6 points)**
- **Conclusion (8 points)**
- **Applications and Recommendations for Further Use (8 points)**

Sample Write-Up (NOTE: I did this experiment using water instead of oil)

A) Statement of Problem

How will the type of paper used (IV- printer paper, Bounty paper towel, cardstock, and newspaper) affect the amount of water it will be able to absorb (DV)?

B) Hypothesis

If the paper is thicker (IV), it will be able to absorb more water (DV). The papers from thickest to thinnest are: Bounty paper towel, cardstock, printer paper, and newspaper.

Rationale: This is because thinner papers will become saturated faster than thicker papers, which means they will be able to absorb less water.

C) Variables

a. **Independent Variable**: The type of paper used. Operationally, the type of paper will be used to determine how the thickness of a material affects how much oil it will be able to absorb. The 3 levels are Bounty paper towel, cardstock, and newspaper, and the SOC (Standard of Comparison) is the printer paper.
b. **Dependent Variable**: The mass (in grams) of oil that the paper will be able to absorb. Operationally, this will be used to measure how much oil can be absorbed by different materials.
c. **Control Variables**:
    i. The size and shape of the samples of paper (we will be using 2cm by 2cm square samples)
    ii. The amount of oil given for the paper to attempt to absorb (we will be using 1 teaspoon)
    iii. The collection method of the paper out of the oil (not squeezing it or "wringing it out" with the tweezers)
    iv. The type of oil/substance that the paper will attempt to absorb (don't use oil for one and water for another. We will be using water for the sake of not making a mess with oil)

D) Standard of Comparison

The SOC will be the printer paper. This is because printer paper is very commonly used and readily available, and it is of a relatively average thickness compared to the other materials.

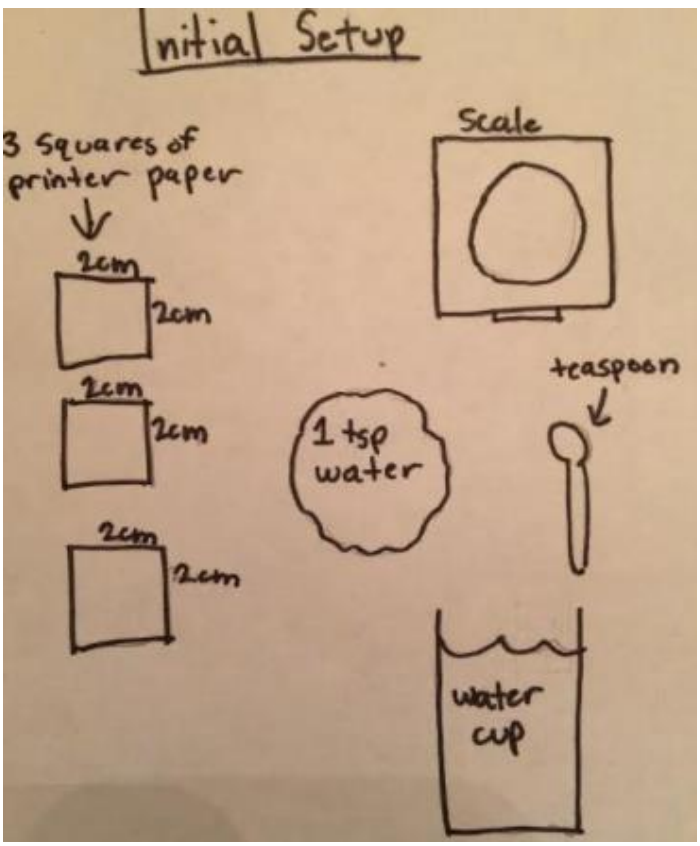
E) Materials

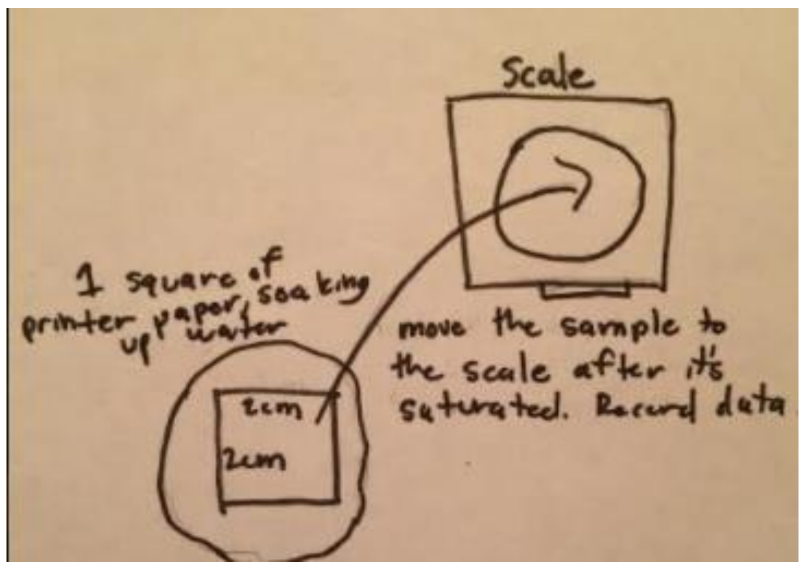
- Safety goggles
- Tweezers
- Scissors
- Scale that measures in grams to the 0.01
- 3, 2x2 cm squares of printer paper
- 3, 2x2 cm squares of newspaper
- 3, 2x2 cm squares of cardstock
- 3, 2x2 cm squares of Bounty paper towel
- ¼ cup of tap water
- 1 teaspoon
- 1 dishrag

F) Procedure

1) Gather all materials listed above, and put on safety goggles. Make sure that your squares of paper are cut to the appropriate size.
2) Weigh 1 square of printer paper using the scale, and record the mass (in grams, to the 0.01) on the data table.
3) Take 1 teaspoon of water and put it on the table in front of you. Allow it to spread out into a circular shape.
4) Take the printer paper that you weighed and place it in the water, allowing it to absorb as much as possible.
5) When the paper appears saturated, use tweezers to take it out of the water and place it on the scale. Record the mass on the data table.
   a. Subtract the original mass of the paper from the new mass and record it on the data table under "Mass of oil absorbed".
6) Throw away the used square of paper. Use the dishrag to wipe the water away.
7) Repeat steps 2-6 with your 2 other squares of printer paper. These are your other 2 trials for the SOC. Make sure to record your values in the appropriate spaces in the data table (labeled trial 2, trial 3).
8) Repeat steps 2-6 with the 3 levels of IV (newspaper, cardstock, and Bounty paper towel). Each square of each material is a different trial, so you should do 9 total trials (3 level of IV * 3 trials). Remember to record all data.
9) Clean up the lab station.

Diagrams:





G) Qualitative Observations

Relating to our results, we noticed that, on average, the bounty paper towel held the most water, while the cardstock held the second most, printer paper held the third most, and the newspaper held the least. This was probably because the paper towel is specifically designed to hold the maximum amount of liquid possible, while the other 3 types of paper are not. Also, it is thicker than the other 3 types of paper, which means that it would be naturally able to absorb more water. Newspaper, on the other hand, is significantly thinner than paper towel, which explains why it held the least amount of water.

Relating to our procedure, we noticed that it generally worked quite well and allowed us to run the experiment in an accurate manner. The repeated trials system was easy to follow, and we did not have problems understanding which sample of paper we were supposed to test. We did not deviate at all from our procedure.

Not directly relating to the dependent variable (the mass of water held), we noticed that the different materials absorbed water at different rates. For example, the paper towel and newspaper absorbed water relatively faster than did the cardstock and printer paper. This is probably because, as previously explained, the paper towel is designed to soak up the most water possible. Also, the newspaper absorbed water so quickly because it is thin and thus quickly saturated. On the other hand, the paper and cardstock did not absorb water very quickly, probably because they are neither exceptionally thin nor designed to absorb water. It is important to note that the absorption speed is not necessarily correlated with the mass of water held, as newspaper absorbed water very quickly, but it was able to hold the least amount.

Throughout the course of the experiment, we noticed a variety of interesting factors including the fact that, at the beginning of the experiment, it was very easy to organize and set up. A slight problem came in that it was a bit difficult to completely wipe down the area after each trial, but that did not pose any major issues. At the end of the experiment, we noticed that our data points had all been very consistent, fluctuating by not more than 0.03 grams.

H) Quantitative Data- Data Table

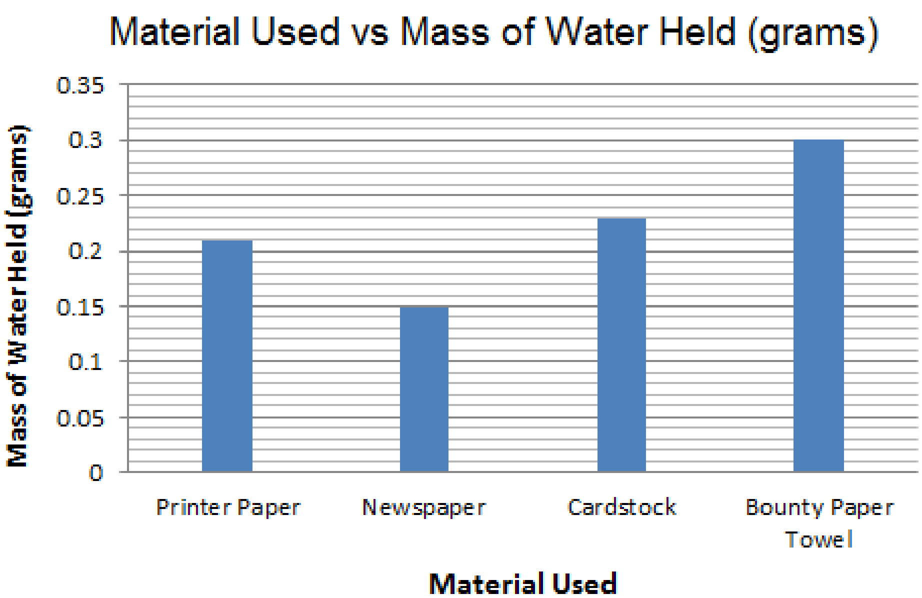
All Raw Data- The Initial Weight, Final Weight, and Mass of Water Held for Each Material

Material	Initial Weight (grams)	Final Weight (grams)	Mass of water held (grams)
Printer Paper (Trial 1)	0.03 grams	0.17 grams	0.20 grams
Printer Paper (Trial 2)	0.03 grams	0.20 grams	0.23 grams
Printer Paper (Trial 3)	0.03 grams	0.18 grams	0.21 grams
Newspaper (Trial 1)	0.02 grams	0.17 grams	0.15 grams
Newspaper (Trial 2)	0.02 grams	0.18 grams	0.16 grams
Newspaper (Trial 3)	0.02 grams	0.17 grams	0.15 grams
Cardstock (Trial 1)	0.05 grams	0.28 grams	0.23 grams
Cardstock (Trial 2)	0.05 grams	0.27 grams	0.22 grams
Cardstock (Trial 3)	0.04 grams	0.28 grams	0.24 grams
Bounty Paper Towel (Trial 1)	0.03 grams	0.33 grams	0.30 grams
Bounty Paper Towel (Trial 2)	0.02 grams	0.31 grams	0.29 grams
Bounty Paper Towel (Trial 3)	0.03 grams	0.34 grams	0.31 grams

Condensed Data Table Showing Average (Arithmetic Mean) Mass of Oil Held by Each Material

Material	Average Mass of Oil Held (grams)
Printer Paper	0.21 grams
Newspaper	0.15 grams
Cardstock	0.23 grams
Bounty Paper Towel	0.30 grams

I) Graph



J) Statistics

Table Showing the Mean, Range, Median, and Mode Grams of Water Held with Each Material

Material	Mean	Range	Median	Mode
Printer Paper	0.21 grams	0.03 grams	0.21 grams	No mode
Newspaper	0.15 grams	0.01 grams	0.15 grams	0.15 grams
Cardstock	0.23 grams	0.02 grams	0.23 grams	No mode
Bounty Paper Towel	0.30 grams	0.02 grams	0.30 grams	No mode

Overall Mean, Range, Median, and Mode for the Amount of Grams Held:

- **Mean:** 0.224 grams (*Division C would round to 0.22 grams because of sig figs*)
- **Range:** 0.16 grams
- **Median:** 0.225 grams (*Division C would round to 0.23 grams because of sig figs*)
- **Mode:** 0.15 and 0.23 grams

K) Analysis/Interpretation of Data

Relating to all of our data, we noticed that our values were all fairly consistent. As previously explained, the amount of water held was greatest in the thickest material (the paper towel) and less in the thinnest material (the newspaper). This means that the paper towel would likely be the ideal material to clean up the oil spill, as you would get the most oil absorbed for the fewest square units of material. Additionally, there were a few unusual data points: Trial 3 of the Bounty Paper Towel (0.31 grams) deviates from Trial 2 (0.29) significantly. This could have been due to errors such as a slightly different-sized sample being cut or impurities in the material itself. It does not, however, deviate far enough from the norm that it puts the conclusiveness of our experiment in question- it is still evident that the paper towel was able to hold the greatest amount of water. Likewise, we noticed 2 related trends in our experiment: The thicker the material, the more water it was able to absorb, and, inversely, the thinner the material, the less water it was able to absorb. To give more detail, this is shown by the fact that the average of the thickest material, bounty paper towel, was 0.30 grams absorbed, while that of newspaper (the thinnest material) was a mere 0.15 grams. The values of the cardstock (average 0.23 grams absorbed) and the printer paper (average 0.21 grams absorbed) were not significantly different from each other, probably because cardstock and printer paper are relatively similar in thickness. Paper towel and newspaper, however, differ quite a bit in thickness.

L) Possible Experimental Errors

With our experiment, there were a variety of errors that could have taken place. For example, the squares of material we cut might not have been exactly 2cm by 2cm. This would have caused our mass values to be either smaller or larger than they should have been, respectively. Also, a more common error that could have easily taken place is the fact that the amount of water measured may not have been *exactly* 1 teaspoon. Because the water was measured in grams absorbed, this would not have had a significant impact on our overall results, but it is still important to attempt to avoid these types of errors in the future. Another possible error is the fact that while we transferred the material from the water to the scale, some of it may have dripped off, thus becoming lost. This would have caused the mass of water absorbed values to be smaller than they should have been. To lessen the potential effects of this error in the future, we should move the scale as close to the water as possible, thus reducing the potential for dripping. Relating to the data collection, we used an electronic balance scale to record all values. This is more reliable than other methods of measurement, as the scale reduces potential for human error in weighing. As long as the scale was correctly zeroed out when we placed the material on it, it gave us an accurate reading. Also, it does not appear that any of these possible errors had a detrimental effect on the accuracy of our values. This can be seen in the fact that none of the materials had a large deviation in values between the 3 trials. The most deviation we saw was 0.03 grams of difference with the printer paper, and this was not enough to have any affect the conclusiveness of our data. Because our values were generally very consistent (as can be seen by examining the 3 trials for each material in the data table), it is clear that the errors discussed were not significant enough to alter the credibility of our results.

M) Conclusion

In conclusion, we have chosen to accept our initial hypothesis, which was that if the paper is thicker, it will be able to absorb more water. This is because, after arranging the papers in order of thickness, we predicted that the Bounty paper towel would be able to absorb the most water, while the newspaper would be able to absorb the least. This was correct, as the paper towel absorbed an average of 0.30 grams, while the newspaper only absorbed 0.15 grams. Also, the two "medium" thickness materials (cardstock and printer paper) absorbed a "medium" amount of water (0.23 grams and 0.21 grams, respectively).

N) Applications and Recommendations for Further Use

After analyzing the results of our experiment, we have determined that there are numerous ways we could improve this specific experiment. For example, we need to make sure that the scale is located close enough to the water testing area so that water cannot drip off of each material while we are moving it to the scale. Also, we should have a more accurate way of measuring the water, such as using a micropipette to test with a precise amount each time. However, this may not be possible as micropipettes are very expensive. Additionally, as always, doing more trials would improve the credibility of our results. Lastly, we would try to find a way to pour the water such that it does not excessively spread out (possibly using less water). This would reduce messes and allow us to get a more accurate measurement.

Other ways to look at our hypothesis include analyzing the speed at which each material becomes saturated instead of the mass of water each material can hold. This would provide scientists with important insight into how often they would need to replenish materials being used to clean up oil spills, as clearly not all materials can absorb at the same rate. (eg: How does the thickness of the material affect how fast it can absorb water?) Additionally, we could observe which 2 materials working together can absorb the greatest amount of water. This could be especially important for scientists when taking into consideration cost limitations- if one material was especially expensive, they could use only a relatively small amount. On the other hand, it may be more cost efficient to combine 2 or more materials with various properties (possibly combining a high absorption speed material with a high absorption mass material).

For a future experiment, we could test how the materials can absorb oil when *mixed with* another liquid, such as salt water. This would be a viable future experiment because, practically speaking, scientists need to observe which materials have the highest capacity to work with heterogeneous substances, as those are most often found in nature.

This experiment has a variety of practical applications, one of the most important being that it can be used to determine the most efficient way to clean up an oil spill. By testing which material can absorb the most amount of "oil" per square centimeter, scientists can determine how to clean up a spill using the least amount of material. Another possible application is that it can be used by paper towel companies to determine how to maximize the performance of their product. Likewise, it can be used by consumers to determine which type of paper towel will give them the best value for their money.

Test 2

Topic: Parachutes

Background: A parachute can be defined as a "device used to slow the motion of an object through an atmosphere by creating drag" (Source: Wikipedia). You are in charge of a company that designs parachutes for skydivers, and you are trying to determine how to optimize parachute performance. Your job today is to conduct an experiment using the given materials that demonstrates how any relevant factor can impact any aspect of parachute performance.

Materials:

- 1 plastic shopping bag
- 1 paper shopping bag
- 1 small plastic cup
- 1 roll of masking tape
- 5 marbles (of identical size)
- 1 electronic scale that measures in grams
- 3 meters of string
- 1 plastic spoon

If you brought the following materials, you may use them:

- Stopwatch
- Ruler/Yardstick

Remember, your write-up must contain all of the following elements:

A) Statement of Problem (4 points)
B) Hypothesis (8 points)
C) Variables
  - **a. Independent Variable (6 points)**
  - **b. Dependent Variable (6 points)**
  - **c. Control Variables (8 points)**

D) Standard of Comparison (4 points)

E) Materials (6 points)
F) Procedure (12 points)
G) Qualitative Observations (8 points)
H) Quantitative Data- Data Table (12 points)
I) Graphs (10 points)
J) Statistics (6 points)
K) Analysis/Interpretation of Data (8 points)
L) Possible Experimental Errors (6 points)
M) Conclusion (8 points)
N) Applications and Recommendations for Further Use (8 points)

Sample experiment: (NOTE: this would NOT be included in the test that you give people; this is just an example of a way to interpret the background/materials list) How does the amount of weight (marbles) in a parachute affect how long it will take to hit the ground when dropped from a constant height?

Test 3

Topic: CO_2 Production

Background: Carbon Dioxide (CO_2) is the most commonly emitted greenhouse gas, accounting for 65% of global greenhouse gas emissions in 2010 (Source: EPA). In order to attempt to target climate change, it is necessary for climate scientists to monitor the levels of CO_2 being produced from various sources and attempt to find ways to lessen these emissions. Your job today is to design an experiment that will measure the effect of a factor of your choice on levels of CO_2 production, and then explain how your findings can be applied to environmental science.

Materials:

- 1, 250mL beaker
- 3, 150mL beakers
- 1 plastic pipette
- Sink (Unlimited tap water)
- 50mL of acetic acid (CH3COOH)
- 50 grams of sodium bicarbonate (NaHCO3)
- 50 grams of table salt (NaCl)
- 50 grams of silver nitrate ($AgNO_3$)
- Rubber stopper

If you brought the following materials, you may use them:

- Stopwatch
- Ruler/Protractor

Remember, your write-up must contain all of the following elements:

A) Statement of Problem (4 points)
B) Hypothesis (8 points)
C) Variables
   a. Independent Variable (6 points)

   b. **Dependent Variable (6 points)**
   c. **Control Variables (8 points)**

D) Standard of Comparison (4 points)
E) Materials (6 points)
F) Procedure (12 points)
G) Qualitative Observations (8 points)
H) Quantitative Data- Data Table (12 points)
I) Graphs (10 points)
J) Statistics (6 points)
K) Analysis/Interpretation of Data (8 points)
L) Possible Experimental Errors (6 points)
M) Conclusion (8 points)
N) Applications and Recommendations for Further Use (8 points)

Sample experiment: (NOTE: this would NOT be included in the test that you give people; this is just an example of a way to interpret the background/materials list) How does the amount of sodium bicarbonate (NaHCO3) added to 10mL of acetic acid (CH3COOH) affect the amount of CO_2 that will be produced?