

ENGR 4040: Buoyancy and Density

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Introduction

After thorough research and comparison, we came up with a variety of experiments to teach 7th and 8th grade students about specific topics in the scientific field. The specified areas were buoyancy, density, and great civilizations with an emphasis on ancient navigation techniques and math skills. Before researching topics, it was first necessary to determine working definitions of buoyancy and density. Buoyancy is related to buoyant force which is a force that acts on an object causing it to float. Basically an object will float when the buoyant force is greater than its weight. Density at its most basic is mass per unit volume. Ancient navigation is using various tools combined with astrology to determine how to travel from one place to another.

After talking with Mr. Foster, the teacher/client we are in contact with, we decided to focus on our buoyancy experiment. That was decided to best fit his students' needs and work best with the knowledge they currently have. The purpose of this memo is to present options for experiments regarding buoyancy, density, ancient navigation techniques, and also to discuss our feedback with the teacher, our decision choice for our project, and the cost analysis of our chosen experiments. We will also be presenting the feedback we received from the students who tested our experiments.

Buoyancy Experiments

The first experiment option demonstrates how submarines take advantage of buoyancy to make them move up and down, or stay in the same position. The buoyancy of the submarine changes when air is added or removed from the ballast tank. This experiment will model a submarine in water and what happens when air is reduced or expanded in our own ballast tank, or plastic bottle. The materials consist of clay, a pen cap, and a plastic bottle with top, which should be rather inexpensive. Clay is rolled into a ball and stuck on the stem of the pen cap which is then placed in the water. The bottle is then filled to the brim and sealed and squeezed. When the bottle is squeezed, the pen cap "submarine" should sink because the gas inside the bottle will shrink due to the pressure increase inside the bottle ($PV=nRT$.) One possible concern could be if the bottle isn't sealed well enough and the gas seeps out of the top causing the submarine not to sink. This can easily be avoided if we make sure the bottles are sealed tight.

The second option for this topic is an experiment involving a can of both diet and regular soda immersed in water. This experiment brings up the concepts of buoyancy as well as density. The additional materials required for this experiment are a mass balance, a container to hold water (large enough for a soda can), one empty can of each type of soda, plastic foam, metal washers, and paper and pencils for recording data. This experiment also appears to be fairly inexpensive. The experiment entails a demonstration of the buoyancy of regular soda compared to diet. It then requires that the students take the empty soda cans and make them neutrally buoyant using the foam and washers. In doing the hands on portion of the experiment, it is required that the students determine masses, volumes by water displacement, density, and look at comparisons between the density of water and the density of the soda. A variety of discussions regarding the importance of neutral buoyancy in engineering design for energy efficiency, the reason why the diet soda floats and the regular sinks, and a number of other things can be included. The constraints for this experiment may be the ease of transporting materials, and possibly the level of difficulty. It is necessary to find out the extent of knowledge the students have on these topics.

Density Experiments

The first possibility regarding density is an experiment involving a 100 ml graduated cylinder, different sized samples of the same metal shot, a 30 ml beaker, a balance, water and spreadsheet software (Excel). The students should be divided into groups of two, but teams of 8 (or similar divisions). The general idea of this experiment is to first have each group of two take a series of mass and volume measurements involving the metal shot and water. The groups then share their data with the team so as to have four sets of data. The data recorded will then be plotted (mass of shot vs. volume of shot) in Microsoft Excel and a trendline will be shown. The slope of this trendline is equal to the average density of all of the four trials. This average density can then be compared to the density of each individual group. This experiment makes it possible to discuss such topics as significant digits and percentage error along with encouraging teamwork and the use of technology in analyzing data. The obvious constraint is the access to computers and Microsoft Excel.

Another possible density experiment will show how liquids of different densities separate themselves. Three liquids of different densities (like molasses, oil, and water) are put in a container and are observed to see how they separate from each other. The least dense (the oil) will end up on the top, while the densest (molasses) will end up on the bottom with the water in the middle. A piece of plastic, a grape, and a piece of cork will be added in order to show that each object will sink to the level of the liquid that has a greater density than the density of the object. One problem could occur if the water and molasses are added one right after the other since they will begin to mix. Again, this experiment appears to be fairly inexpensive to complete. While the experiment itself is almost simplistic, a variety of lessons, questions and predictions can be included in the actual lecture.

Ancient Navigation Experiment

The most feasible experiment regarding ancient navigation techniques was the creation of a sextant. Sextants are an angling measuring instrument used to measure the angle of a celestial body over a horizontal line of reference. The experiment involves a CD with a case, sticker paper, 2 small glass mirrors, legos, glue, a paper cutter, a ruler and scissors. The CD sextant can be used for celestial navigation and coastal navigation and makes use of simple trigonometric relations. A set of instructions need to be followed to create the sextant and a number of assignments can be created involving this. The lecture could involve the history of such instruments as well as simple geometry (such as obtuse/acute angles). Figure 1 shows what the finished product would look like.

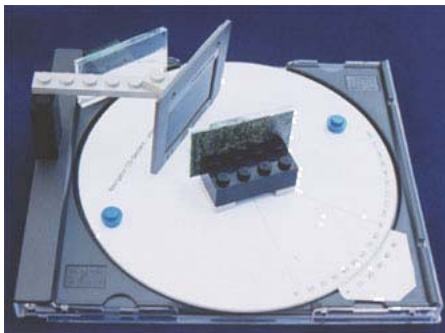


Figure 1

This experiment appears to address the ancient navigation aspect as well as the mathematical component. The concern with this would be the level of math (geometry, trigonometry) that the students have and whether or not the construction of this would be overly time consuming and difficult. The last two concerns could be easily remediated by assembling small portions of it beforehand.

Considerations

It was necessary to take a number of issues into consideration when analyzing the experiments. One of these considerations was the time constraint. We only had an hour and a half to perform the experiments and get the concept across. Another consideration was the level of knowledge of the students. We needed to take into consideration the fact that the students were coming from different schools around Kalamazoo and therefore had different backgrounds coming into this classroom. Also the level of mathematics skills was extremely important in determining which experiments to choose. All of the students were in the top 2 percent of their respective classes, so that was also important to note. Another important factor in our decision making was the access to equipment and materials. It was important to find out whether or not we had computers, water and sinks available to us. Also we needed to find out the availability of mass balances, plastic containers and a number of other materials we required for the experiments.

Customer Feedback

In order to determine which experiments would best help our clients, we decided to meet with them to talk over our topics. Mr. Foster was available to meet with us to talk over our topics and was very excited about us coming to do the experiments. After discussing our topics and ideas, he thought that focusing on one area, instead of all three, would be the best way to nail in the concept. Foster thought that two experiments addressing varying aspects of the concept would be sufficient. He also agreed with us that a quick lecture on the subject to introduce or reintroduce the topic should ensue followed by the hands-on experiments. It was also good to learn from Mr. Foster that the students we would be teaching would be about 25-26 6th graders from varying schools, instead of the 7th and 8th graders we had originally thought. We set a tentative time and date for 9:30am to 11am on Wednesday, November 16, 2005. He wasn't sure if the students' attention spans could handle much more than that. We also learned that there we would be doing the experiments in an area that had sinks and many supplies that we could use. Mr. Foster appeared to be very excited and happy about our topics.

Narrowing it Down

During our meeting with Mr. Foster, we asked him about the students' math skills. He didn't think that the students would have any experience with trigonometry yet, but he did think that they could solve for one variable. After learning that they didn't know any trigonometry, we decided that we weren't going to be able to do the ancient navigation experiment since the entire calculations involved trigonometry. The density experiments were determined to be good, but buoyancy was a topic that needed to be covered. We then discussed our buoyancy experiments. He was very excited about the two experiments that dealt with buoyancy, so we decided to choose buoyancy for our topic. We plan on using the pen cap submarine experiment and the diet coke vs. regular coke experiment which were discussed above. We believe these two experiments will do a wonderful job illustrating the principles of buoyancy. The lesson plans for the two experiments can be seen in Appendix A.

After deciding on these two experiments, we went over the list of materials required to determine what would need to be purchased and what was available for use. We determined that the plastic containers and mass balances would not need to be purchased. The water bottles could be saved up from daily use and also did not need to be purchased. Calculators, pencils and paper were also already in the classroom. With this discussed, the meeting was adjourned and the preparation for the two chosen experiments could begin.

Cost

After narrowing our project down to the two buoyancy experiments, we decided to do a cost analysis to determine the amount of money these experiments are going to cost us for 26 students. The costs evaluated for each of the experiments can be seen in the following table.

Pen Cap Submarine Experiment			Diet Coke vs. Regular Coke		
Item	Unit Cost	Unit Cost for 26 students	Item	Unit Cost	Unit Cost for 26 students
Plastic Bottle	\$0.00	\$0.00	Diet Coke	\$8.40	\$16.80
Clay	\$19.59	\$19.59	Regular Coke	\$8.40	\$16.80
Pen Caps	\$0.99	\$2.97	Plastic Foam	\$18.96	\$18.96
			Mass Balance	\$0.00	\$0.00
			Container	\$0.00	\$0.00
			Metal Washers	\$0.00	\$0.00
			Paper	\$0.00	\$0.00
			Pencils	\$0.00	\$0.00
Total Cost		\$22.56	Total Cost		\$52.56

Table 1: Estimated Experiment Costs

The reason for the zero dollar amounts for the pen cap submarine experiment is that we thought that we could collect enough plastic bottles for us to not have to buy them. The materials listed as \$0.00 dollars in the regular coke vs. diet coke experiment are listed as so because the teacher told us that he would supply them. The combined cost of these two experiments is \$75.12, which should be within our budget.

Student User Test Response

After doing a trial run of our two experiments with two seventh graders and a fifth grader, a few alterations have been made in the experiments. We determined that we require a more structured outline for our lesson plans. There were points when we were not entirely sure what to discuss with the students. To fill those voids we have added more material to our lesson plans. Also, we decided that we need to supply calculators. That was something we overlooked prior to the user test and it is necessary to do some of the calculations.

In speaking with the students after the experiment, we obtained more advice on how to improve the experiments. They suggested that the concept of displacement needed more explanation and also that some of the directions needed clarification. Overall, the students enjoyed the experiments. They had enough background knowledge to make educated hypotheses, but still learned new information. The results of the student writing activities from the user test can be seen in Appendix B.

Classroom Experience

The final deciding factor in the success of our project was the classroom experience. Overall, the classroom experience proved to be beneficial to the students, their teacher and us. The students proved to be very adept conceptually and made predictions extremely close to the actual answers. We were very impressed with the level of knowledge of the students regarding these topics. Some of them actually knew why diet soda floated and regular soda sank. It appeared that they had enough base knowledge of the topic of buoyancy to make educated hypotheses. They did not have too much background that they weren't able to learn more and build on the concept, so they were still able to gain something from the experience. It was rewarding to see that the children were responding well to our experiments and excited about what we had to present to them.

A number of issues were encountered when the experiments were introduced. Right away we realized that more students were in the classroom than we had been told previously. Because of this, the sizes of the experiment groups were a little larger than we had hoped for. This made it difficult for all of the students to participate in the experiments and made it easy for some of the students to stand back and watch. Because not everyone was able to participate, a few of the students were distracted and this made it difficult to conduct the experiments. Another issue we had was that the environment we were teaching in was not exactly conducive to learning. Rather than a classroom setting, we were in a kitchen in order to have access to the sinks and water. There happened to be a pool table in the kitchen and this proved to cause a lot of distraction. The final issue was that it was difficult to explain the concepts. This was due to the different paces of each individual group. Because they all did things at different speeds, we had to re-explain each concept to each separate group. This made the experiments last a little longer than we had planned.

Recommendations

Coming out of the classroom experience we were able to determine a number of things we would have changed. The main recommendation was to have smaller groups. It was difficult to keep the students attention and to have them all participate with the size groups that we had. If we were to do it again we would provide more supplies in order to minimize the number of students per group and maximize the participation of each student. We also would conduct the experiments in an environment that the students associated with learning. A classroom setting would have allowed the students to focus better and ultimately get more out of the experiment. Also, we had problems with space to do the written activity. The space issue combined with the fact that water from the experiment was messy was the basis for the recommendation to do the written activity in a separate area. This would make it much easier to get the students to focus on the activity and take their time. One final recommendation would be to provide all of the formulas rather than the ones we thought were necessary. We only provided the density

formula and it would have been useful to provide the formulas to calculate volume by water displacement.

Conclusion

These potential experiments teach students about important topics in science. The buoyancy experiments explain the concept of buoyant forces as well as encourage the students to ask why things occur the way they do. The density experiments explain what density is and promote teamwork, math skills and understanding real life concepts. Finally, the sextant examines great civilization's navigational techniques and gives them a math lesson on basic trigonometry and angles.

A number of issues needed to be taken into consideration to ask at the meeting with our client, Mr. Foster. The meeting with Mr. Foster really helped us in finalizing our experiments. He gave us a better idea of the kinds of students, skills of the students, and environment in which we would be performing these experiments. His excitement about our buoyancy experiments really made them easy to choose. After analyzing the costs of the experiment, we were happy to see that they would be within our budget as well.

The user test was extremely useful in allowing us to be able to determine the improvements that needed to be made in our experiments. The necessary changes were made in the experiments in order to help them go more smoothly in the final classroom test. The overall classroom experience went well. There were a few changes we would make such as smaller groups, a different setting and providing all of the formulas. We feel that the overall experience was beneficial to the students as well as to us as the teachers. It was extremely rewarding to interact with the youth of Kalamazoo and further their knowledge in the areas of science and mathematics.

**Appendix A:
Lesson Plans**

Lesson Plan: Buoyancy
Teacher Materials

Objective:

To help students understand the principles of buoyancy.

Standards Addressed:

- (C) I.1 m.1 – Generate scientific questions about the world based on observation.
- (C) I.1 m.2 – Design and conduct scientific investigations.
- (C) I.1 m.4 – Use metric measurement devices to provide consistency in an investigation.
- (R) II.1 m.3 – Show how common themes of science, mathematics, and technology apply in real-world contexts.
- (PME) IV.1 m.1 – Describe and compare objects in terms of mass, volume, and density.
- (PME) IV.1 m.2 – Explain when length, mass, weight, density, area, volume, or temperature are appropriate to describe the properties of an object or substance.

Useful Terms:

Buoyancy: The tendency or capacity to remain afloat in a liquid or rise in air or gas.
- or - The upward force that a fluid exerts on an object less dense than itself.

Density: The mass per unit volume of a substance under specified conditions of pressure and temperature.

Mass: The physical volume or bulk of a solid body.

Volume: The amount of space occupied by a three-dimensional object or region of space, expressed in cubic units.

Displacement: The volume or weight of a fluid displaced by a floating body of equal weight.

Ballast: Heavy material that is placed in the hold of a ship or the gondola of a balloon to enhance stability.

Materials Needed:

- Plastic bottle with top (must be air-tight)
- Extra plastic tub
- Clay
- Pen cap

- Water
- Diet soda
- Regular soda (same brand as the diet)
- Container to hold water
- Mass balance
- Empty cans of diet and regular soda
- Plastic foam
- Metal Washers
- Paper
- Pencils
- Tape (waterproof)
- Scissors
- Rulers
- Markers/Crayons/Colored Pencils (optional)

Teacher Experiment Procedures:

Pen Cap Submarine –

Background information:

This experiment shows how buoyancy is used by submarines in order to make them move up or down in the water. Submarines move depending on their buoyancy. When air is increased or decreased from the ballast tank, then the buoyancy of the submarine is affected. This pen cap submarine experiment will simulate a submarine in the water and what happens when the air in the ballast tank, our plastic bottle, is increased or decreased. When the bottle is squeezed, the submarine will sink because air inside the bottle will decrease and the pressure inside the bottle will increase, forcing the pen cap submarine downward ($PV=nRT$). Likewise, if the bottle is unsqueezed, then the air inside the bottle will increase and the pressure will decrease, forcing the pen cap submarine upward.

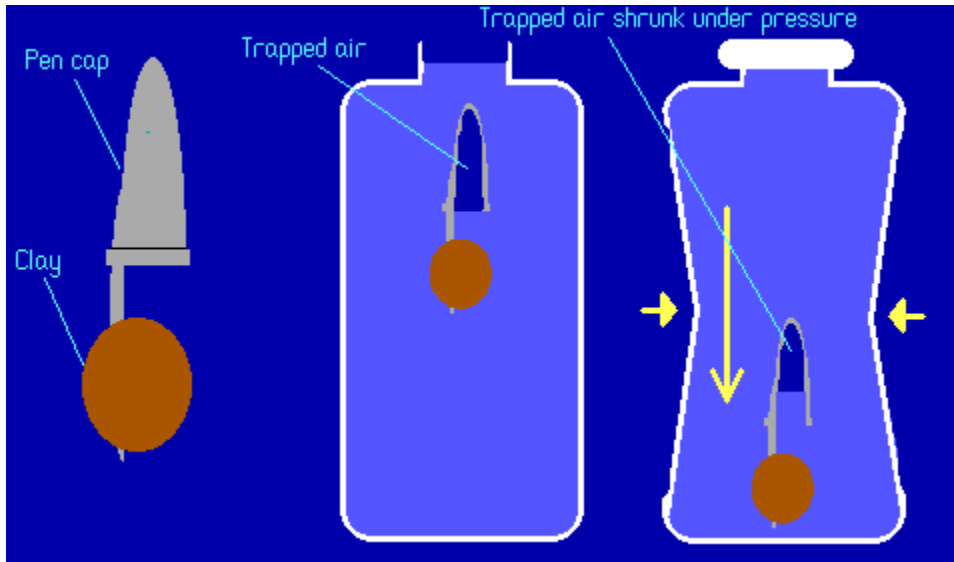
Possible Problems:

You have to make sure that the pen cap with clay on it will fit through the top of the bottle. Also, you need to make sure that the bottle is sealed tightly to prevent water and/or air to seep out.

Procedure for Experiment:

1. Talk about how submarines move in the water. (depends on their buoyancy – adjusting the amount of air in the ballast tanks)
2. Have the students create their pen cap submarines according to the student directions.
3. Test the students' submarines in the container of water until they float just below the surface of the water. – This is neutral buoyancy.

4. Fill the bottles with water and let the students place their submarines inside. Have them tightly close the container and begin experimenting with increasing and decreasing the amount of air in the bottle.
5. Have the students fill out the worksheet provided. Discuss with the whole class what the students came up with for answers.



(<http://www.unmuseum.org/exsub.htm>)

Soda Can Experiments –

Background information:

These experiments explain what buoyant force is and how it relates to an objects' weight. Buoyant force is a force that acts upon an object causing it to float. If the buoyant force is greater than the weight of an object, the object will float. If the buoyant force is less than the weight of an object, the object will sink. If the buoyant force is equal to the weight, then the object is neutrally buoyant.

Possible Problems:

One problem that you have to be careful of is that they soda pop cans might not give accurate results if they are different brands, so be sure that you test the experiment before you try it with your students. Also, make sure that the plastic foam is able to be broken into small enough pieces to fit in the can for the second experiment.

Procedure for Experiment:

1. Show the students the unopened cans of diet and regular soda pop. Ask the students what the differences might be between the cans. Have them write on their worksheets what they think will happen if the two different cans are separately placed in water. What will they do once they are placed in the water?
2. Have the students place the regular soda pop in the water (it should sink) and then have them place the diet soda pop in the water (it should float). Have

3. Have the students record what happened to the two different cans of soda pop on their worksheets.
 4. Have students write why they think this happened on their worksheets.
 5. Have a class discussion about their predictions and thoughts about what happened. (Regular soda pop is sweetened with sugar or corn syrup, which is very heavy, diet soda pop is sweetened with artificial sweeteners, which are much sweeter than sugar and are needed in less quantities to sweeten the pop, therefore diet pops are less dense than water and regular pops are more dense than water.)
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1. Have students set up the data table for recording the mass, volume, and density of the empty soda pop cans.
 2. Measure the masses of the cans and read the volumes from the side of the cans.
 3. Figure out the volume of the cans by water displacement.
 4. Calculate the density of the unopened cans. (Mass divided by volume = density)
 5. Add the foam and nails to raise or lower the cans in the water.
 6. Ask students what neutral buoyancy is and how they have been using neutral buoyancy in their experiment.
 7. Ask students why regular soda sinks and diet soda floats. (Regular is more dense than water, diet is less dense than water)