EXPERIENCING THE NATURAL WORLD

Laboratory for Secondary Level Students

Teacher Manual

WOMEN SUPPORTING WOMEN IN THE SCIENCES

Mission Statement

The mission of this lab is to teach secondary school students about floatation, heat transfer and emission, and the mechanics of a volcano and volcanic eruption.

Contents

1. Introduction to WS2 Laboratory Kits

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to primary and secondary school students, predominantly in eastern Africa. The lab kits utilized local resources and included topics that are especially relevant to young girls in order to spur their interest in STEM subjects. From 2020-2023, over 5100 students from eastern Africa at over 40 school sites engaged with our lab kits, with 62% being girls. Following this initiative, WS2 leadership was selected for a Mandela Washington Fellowship Reciprocal Exchange Program which expanded the reach of our kits through a teacher training workshop. With support from the APS Forum on Education, a subset of teachers from this workshop created this new kit, "Experiencing the Natural World", which has been enjoyed by over 300 students to date. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Forum on Education, APS Innovation Fund, Mandela Washington Fellowship Reciprocal Exchange Program, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural

Student Affairs. WS2 gratefully acknowledges the team of teachers that worked on the creation of this lab kit.

1.2. Using this Guide

This manual is to be used by the teacher, and it is similar in content to the student manual but contains additional material, namely: Overview, Fundamental Physics and Materials Science Concepts Covered, Practical Skills, Summary of Experiments, Results, Teacher Pre-Lab These additional sections are intended to provide the teacher with the background and foundation critical for successfully implementing this laboratory kit in the classroom. It is recommended that the teachers of this laboratory go through the guide from beginning to end to familiarize themselves with the laboratory content prior to teaching the laboratory to students. Questions about the laboratory content can be directed at any time to ws2global.org@gmail.com, using the subject line "Question about Lab Kit Content".

IMPORTANT NOTES:

- This laboratory is intended for use with secondary-level students (ages ~12-18), but depending on the specific students' educational background, the content may need to be modified by the teacher to be made simpler or more complex. The teacher is encouraged to also cover the laboratory content at the pace that works best for the students; some younger students may need more time and attention from the teacher and/or facilitator to go through the questions and experiments, while older students may be more independent and require less attention from the teacher and/or facilitator. Thus, the content covered, depth of coverage, and pacing are left to the teacher's and/or facilitator's discretion.
- The content in this lab manual may not fit into the specific curriculum of the school in which it is being taught. It is up to the facilitator(s) and teacher(s) whether they would like to introduce new content or skip certain sections that are not applicable to their classrooms.
- In certain areas, modifications to the supply list may need to be made depending on the availability of the supplies in the specific area in which the lab is being taught. We have attempted to list some alternatives in the supply list, but we understand this list of alternatives is not exhaustive.
- In the experiments, the students are split into groups of three to four. If supplies allow, students may instead be split into groups of two.

1.3. Key Vocabulary

- Up-thrust
    - ✓ Upward acting force on floating bodies in liquids or gases
- Sinking
    - ✓ Drop below the surface of a liquid; drop to a lower level of liquids or gases
- Floating
    - ✓ Remain on the top surface of a liquid
- Fresh water
    - ✓ Water with small concentration of salt
- Salt water
    - ✓ Water with high concentration of salt
- Heat
    - ✓ Form of energy that can be transferred from one point to another due to temperature difference
- Heat transfer
    - ✓ Movement of heat from one point (object) to another, usually from hot region to cold region
- Radiation
    - ✓ Heat transfer in vacuum by electromagnetic wave
- Conduction
    - ✓ Heat transfer through direct contact
- Convection
    - ✓ Heat transfer through fluid like gas or liquid in which warmer portions rise and colder portions sink
- Volcano
    - ✓ Opening in Earth's surface where lava, ash, and gas can escape
- Eruption
    - ✓ Process by which liquid or gas is pushed out at high speed through small opening
- Chemical reaction
    - ✓ Process in which one or more chemical substances are converted to one or more different substances

1.4. Key Questions

- State conditions for an object to float.

- Answer:
  - ✓ Weight of floating object is equal to or less than the up-thrust due to the fluid.
  - ✓ Volume of the fluid displaced by the object is equal to the volume of the object that is submerged.
  - ✓ Density of the fluid must be equal to or greater than the density of floating object.
- Why is white paint preferred over black paint for buildings in tropical climates?
  - Answer:
    - ✓ White paint is a better reflector of light and worse emitter of heat, whereas black paint is a better absorber of light and better emitter of heat.
- What is a volcanic eruption?
  - Answer:
    - ✓ The process by which magma and gas are pushed at high speeds through a small opening in the Earth's surface. The magma that reaches the Earth's surface is called lava.

1.5. Purpose

The purpose of this lab kit is to showcase the physics and science that underpin various aspects of the natural world with which students may interact. The experiments will demonstrate the principles and conditions governing bodies sailing in water, the influence of heat transfer, absorption, and emission on the choice of color of objects, and the process and impacts of volcanic eruption.

1.6. Overview

Through this lab kit, middle and high school/secondary-aged students (ages ~12-18) will (1) apply the knowledge of floating and sinking to objects in water with Archimedes principle, (2) use the knowledge of heat transfer to understand the impact of color on heat emission, and (3) demonstrate the process of volcanic eruption using model volcano that employs a chemical reaction.

1.7. Fundamental Scientific Concepts Covered

The laboratory introduces several key topics related to understanding the natural world: Archimedes' principle and floatation, energy transfer and transformation, volcanic eruption mechanism, and chemical reactions. These basic concepts are critical and relevant to numerous fields including Biology, Earth Science, Physics, Chemistry, Materials Science, and Engineering.

1.8. Practical Skills

- Students will learn how to measure the volume of water and submerged objects.
- Students will gain understanding of what keeps themselves afloat while swimming or in water sailing vessels.
- Students will acquire skills of color selection in paint, clothes, and other objects depending on the climate.
- Students will understand how volcanic eruptions occur and how to safeguard themselves against volcanic eruption.

2. Background on Main Topics

2.1. Let's Take a Trip Outside

There are so many things in the natural world that impact us and the ways we live. Consider all that is around you right now and how it affects your life: your climate, weather, geography, and nearby natural features all can play a significant role in your day-to-day life. Furthermore, underpinning all of these natural processes are some very interesting physics that we do not often think about.

Today, we will consider the underlying science in the natural world on a visit to northern Tanzania, near the active Ol Doinyo Lengai volcano. Here, there is also Lake Natron, a saltwater lake, though nearby larger bodies of water are Lake Victoria, the world's largest tropical lake, and the Indian Ocean. This region is also located quite near to the equator, and its climate is tropical and quite sunny. How might living in a tropical climate near an active volcano with nearby freshwater and saltwater bodies impact your life? What is the science that helps to explain the experiences we have with these parts of the natural world? Let's find out!

2.2. Archimedes' Principle & the Law of Floatation

Archimedes of Syracuse was an ancient Greek mathematician, physicist and engineer who lived in the 3rd century BC. He developed a scientific principle that has come to be named after him. Archimedes' principle states that "when a body is partially or totally immersed in fluid it experiences an up-thrust equal to the weight of fluid displaced". An up-thrust is the upward force acting on bodies in gas or liquid.

The story behind the discovery of Archimedes' principle is well known and often remembered by the phrase "Eureka". According to the legend, king Hiero II of Syracuse commissioned a goldsmith to make a golden crown. However, he suspected that the goldsmith might have mixed some silver into the crown making it impure. The king asked Archimedes to determine whether the crown was made of pure gold without damaging it.

Archimedes pondered the problem and eventually found a solution while taking a bath. As entered the bathtub, he noticed that the water level rose, and he realized that his body was displacing a volume of water equal to his own volume (similar to the example with a rock shown in Figure 1). This observation led him to the principle of buoyancy, which is the power of a fluid to exert an upward force on a body placed in it. He also understood that he could submerge the crown and an equal mass of pure gold in water and determine the difference in the two objects' density by the difference in their volumes. The difference in the densities of the two objects proved the crown was not made of pure gold. Density is related to mass and volume by the equation:

$$density = \frac{mass}{volume}$$

Excited by his discovery, Archimedes reportedly shouted "Eureka" (which means, "I have found it" in Greek) and ran naked through the street of Syracuse to share the news. He conducted further experiments and mathematical calculations to verify

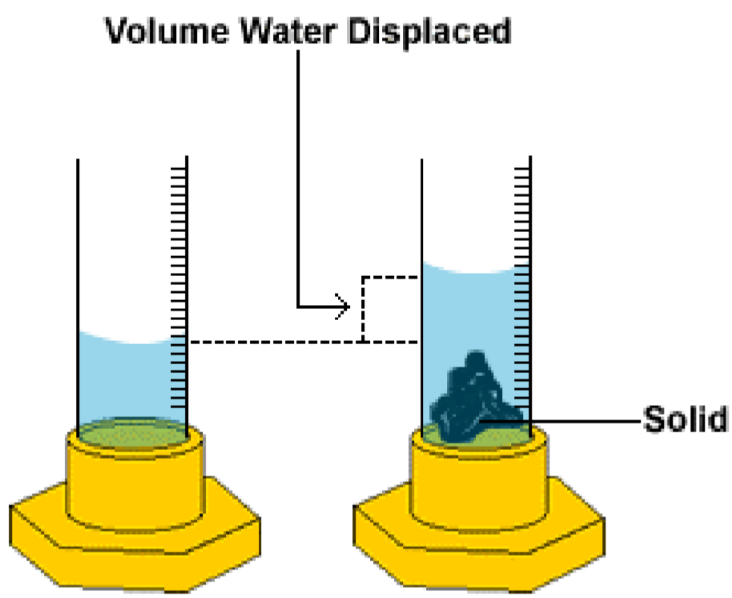

Figure 1. When an object is submerged, it displaces a volume of water equal to its own volume. This Photo by Unknown Author is licensed under CC BY-SA-NC

and explain the principle, and it became one of his most significant contributions to science.

Archimedes' principle has various practical applications. It provides the basis for understanding the behavior of floating objects such as ships and boats and helps in designing and constructing them. Floating is when an object is suspended in liquid or gas: in the case of a liquid, the floating object will remain on the surface of the liquid. On the other hand, sinking objects drop below the surface of the liquid. The density of the object and the liquid matters: an object will float more easily in salt water, or water with a high concentration of salt, than in fresh water, or water with a low concentration of salt, because of the difference in density. Salt water has a larger density than fresh water, so objects sink more in fresh water than in salt water.

In summary, for an object to float, there are conditions that will be met, including that the weight of floating object is equal to or less than the up-thrust due to the fluid, the volume of the fluid displaced by the object is equal to the volume of the object that is submerged, and the density of the fluid must be equal to or greater than the density of floating object. Archimedes' principle has had a significant impact on the development of physics and engineering and helped to lay the foundation for later advancements in fluid mechanics. It remains important even in today's science.

2.3. Heat Transfer

Heat transfer is a fundamental concept in physics and engineering that deals with the exchange of thermal energy between different systems or regions. Specifically, heat is a form of energy that can be transferred from one place to another due to temperature difference, and heat transfer is the movement of heat from one place to another. Heat flows from hot to cold regions. Heat transfer occurs through three different processes: conduction, or direct transfer by contact; convection, or transfer through fluid like gas or liquid in which warmer portions rise and colder portions sink; and radiation, or transfer by electromagnetic waves or photons (light). Examples of these types of heat transfer are shown in Figure 2.

In heat transfer, materials can be placed into two broad groups: good and poor conductors. Good conductors are those materials which allow heat to flow through them easily (for example, metals like iron, silver). Good conductors are used in making motor car engines, pistons, and cylinders due to high thermal conductivity. Poor conductors or insulators are those materials which do not allow heat to pass through them easily (for example, wood, plastic, wool, glass, even air). Insulators like these are used to make handles of saucepans, teapots, and kettles.

An important example of radiative heat transfer is through sunlight. Light from the Sun is incident on the Earth every day, and whether materials absorb or reflect light has important consequences for how much they heat up. Absorbers are materials that gain radiative energy incident on them. For example, clothes that are black are good absorbers and absorb incident light. When placed outside in the sunlight, black clothes dry faster than white clothes, which mostly reflect sunlight. White clothes or bright surfaces are poor absorbers of heat through sunlight as compared to other colors. Radiative heat transfer is thus important in many situations: houses in tropical countries are often painted white or light colors to reflect sunlight and keep the house cooler inside.

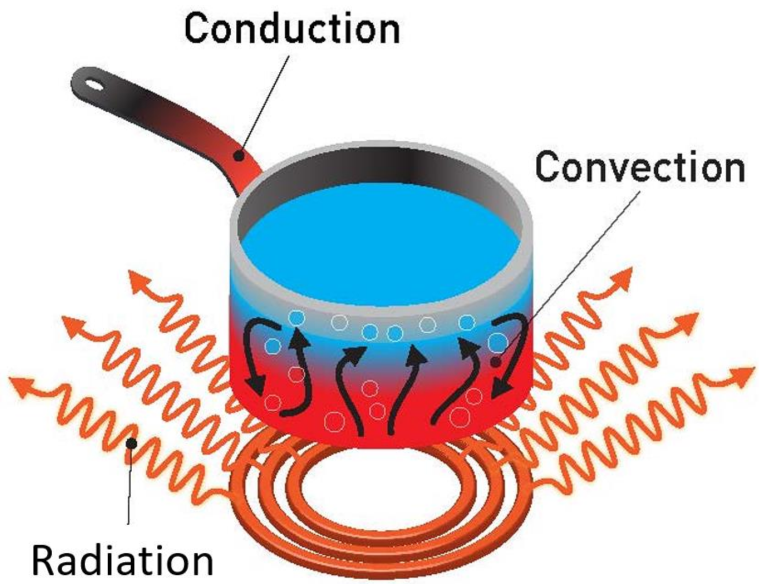

Figure 2. Conduction, convection, and radiation are three types of heat transfer. When you boil water in a pot, all three types are working to heat up the water and the pot! This Photo by Unknown Author is licensed under CC BY.

Color also matters when it comes to emission of heat that is absorbed, regardless of how the heat is absorbed (whether through conductive, convective, or radiative means). Black objects are better emitters of heat than lighter-colored objects. You may have noticed this if you have walked on a black-colored roadway in the bright sunlight: you will feel the roadway emitting a lot of heat. As with heat absorption previously discussed, the impact of color on heat emission also has important implications in selection of paint on buildings, as darker-painted buildings will emit more heat than lighter-painted buildings.

Ancient civilizations such as the Egyptians, Greeks and Romans had practical knowledge of heat transfer through their architectural designs. They used natural convection to improve ventilation and employed insulating materials such as clay and straw to regulate temperature. Today, heat transfer remains a critical area of research and has practical application in numerous industries, including energy, manufacturing, aerospace and environmental engineering. Ongoing advancements continue to deepen our understanding of heat transfer phenomena and enable the development of more efficient and sustainable heat transfer technologies.

2.4. Volcanic eruption

Volcanoes are features in the Earth's crust that allow lava, ash, and gas to escape from a large pool of molten rock beneath the Earth's surface. The molten rock is called magma, and the pool of magma is called the magma chamber. Magma originates from the mantle where high temperature and pressure cause the rock to melt. Magma in the magma chamber is denser than the surrounding rock, thus the rock provides force that tends to drive the magma upward. If the magma finds a path to the Earth's surface, this results in a volcanic eruption, which is the process by which magma and gas are pushed at high speeds through a small opening. The magma that has been erupted to the Earth's surface is called lava. Some volcanoes erupt with an explosive spray of lava and ash, whereas in others the lava flows out of an opening. It all depends on the shape and the opening; the more confined space, the more explosive the eruption. A cross-section of a volcano is shown in Figure 3.

The sandbox model volcano is an example of an eruption where the chemical reaction between vinegar and baking soda produces a gas which pushes the liquid up and out of the container. A chemical reaction is the process by which one or more chemicals are converted into one or more different chemicals. This eruption in the sandbox volcano is similar to an actual volcano where gas builds up underneath the Earth's surface and forces liquid (in the case of a real volcano, magma) up through the hole in the volcano, causing an eruption. When baking soda (a base) comes into contact with vinegar (an acid), they chemically react to form water and carbon dioxide gas. The gas tries to escape from the mixture, creating bubbles that rise to the surface. These bubbles make a fizzing sound and give the impression of a mini volcano eruption. It is important to note that while the mechanics of gas build up and eruption of material in the model volcano is *similar* to an actual volcano, a chemical reaction is not what is responsible for a real volcanic eruption. In a real volcanic eruption, the magma rises because it is less dense than the solid rock surrounding it beneath the Earth's surface.

Are there any benefits to a real volcanic eruption? During real volcanic eruptions, sometimes valuable metallic minerals like zinc, gold, and copper are exposed to the Earth's surface. Magma that sits close to the Earth's surface can also be used to generate geothermal energy. Volcanic eruptions also come with some very negative impacts, as well, such as loss of biodiversity, loss of property and life, environmental pollution, and deformation of landscapes.

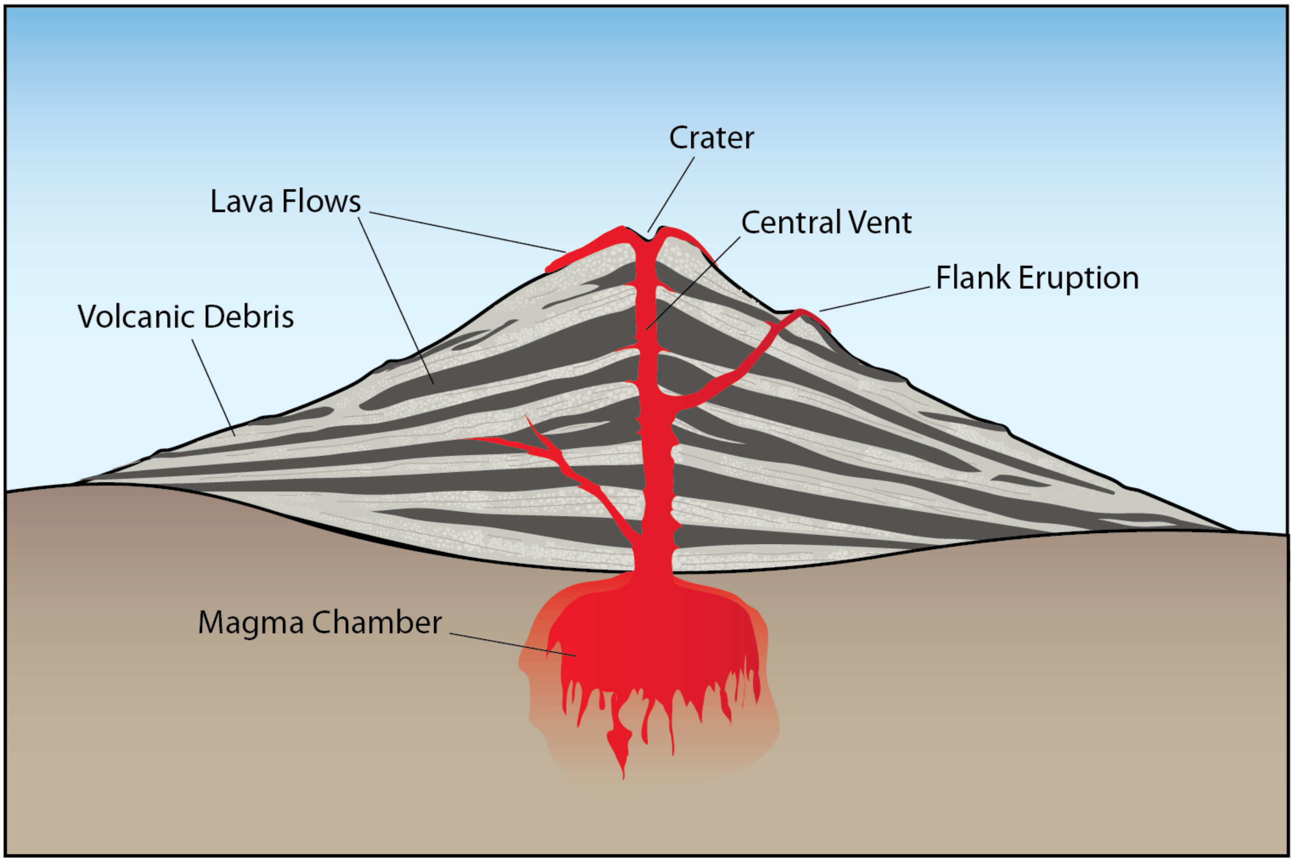

Figure 3. Cross-section of volcano. The magma resides in the magma chamber below the Earth's surface. Magma that finds a way to the Earth's surface is called lava. This Photo by Unknown Author is licensed under CC BY-SA-NC

3. Summary of Experiments

This lab kit consists of two experiments, one demonstration, and one design challenge to understand the concepts of floatation, heat transfer, and volcanic eruption. This investigation starts with an experiment that reinforces how density impacts the ability of objects to float. Next, students will explore the effect of color on heat transfer using a candle as their energy source. Students will then use a chemical reaction to model a volcanic eruption. Finally, a design challenge asks students to consider how to design a boat that floats well on the water. The goals of the experiments and design challenge are the following:

Part I: To demonstrate that an object (egg) floats in the salt water and sinks in the fresh water, owing to the salt water having a greater density than the fresh water.

Part II: To demonstrate that wax melts faster on the side of the can that is colored black because this side emits more heat than the light colored/shiny side.

Part III: To model a volcanic eruption using a chemical reaction between baking soda and vinegar.

Design Challenge: To design a robust boat that floats easily while in the water.

3.1. Supplies List

- Water
- Eggs
- Salt
- Spoons (teaspoon sized)
- Wooden sticks
- Clear plastic or glass jars or cups
- Tin or metal cans (half outside painted black and half painted white or left shiny)
- Candles
- Wax (or other very low melting point material like butter or coconut oil)
- Matches or lighter
- Wood blocks (or metal pieces) to act as stand for metal can
- Empty bottles
- Vinegar
- Baking soda
- Food coloring (natural or synthetic)
- Clay soil
- Wood blocks to act as stand for model volcano

3.2. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- While the lab utilizes some food items, students should not taste or smell any of the chemicals during the experiments.
- Students should handle fire and candles with care, as well as the metal can once it is heated by the candle, to ensure they do not burn themselves.

3.3. Teacher Pre-Lab

Teachers can organize the supplies for the experiments and demonstration ahead of time for each student or groups of 2-4 students (it is encouraged to have students work together):

Part I:

- Each group should have: 2 jars, 2 eggs, 1 spoon, and 1 stirrer. The class can share water and salt.

Part II:

- Teachers should prepare the cans ahead of time for the groups, painting one half black and the other white or left shiny.
- Each group should have: 1 can, blocks to provide a stand for their can, 1 candle, 2 wooden sticks. The class can share the wax and matches or lighter.

Part III:

- Each group should have: 1 wood block base and 1 empty bottle. The class can share the baking soda, vinegar, food coloring, and clay soil.

4. Experiments

4.1. Part I. Effect of Density on Floating Object

4.1.1. *Summary*

In this experiment, we are going to test how added salt to water impacts an object's ability to float or sink.

4.1.2. *Pre-Experiment Questions*

1. How does density relate to mass and volume?
   Answer:
   ✓ Density is mass divided by volume.
2. Why is salt water more dense than fresh water? Your answer should include the words "mass" and "volume".
   Answer:

- ✓ Salt water is more dense than fresh water because the dissolved salt increases the mass of the water without increasing its volume.

3. What would you try to make an object like an egg sink or float quickly in salt water?

   Answer:

   - ✓ If you want the egg to sink, add more fresh water to salt water.
   - ✓ If you want the egg to float, add more salt to the water.

4.1.3. *Supplies*

- Tap water (about 700 mL)
- 2 fresh eggs
- Table salt (about 5 teaspoons or 25 g)
- Spoon
- Stirrer
- 2 clear plastic or glass jars

4.1.4. *Procedure (work in groups of 2-4)*

1. Label two jars as A and B.
2. Measure 350 mL of tap water then pour the measured amount into A.
3. Repeat step 2 for B.
4. Gently lower the fresh eggs into each jar containing tap water (fresh water).
5. Measure five (5) teaspoons of table salt and pour into A
6. Stir and observe what happens to the egg.

4.1.5. *Results*

Jar	Volume of water	Amount of salt	Observation
A	350 mL	5 teaspoons	The egg floats upon adding salt.
B	350 mL	-	The egg remains at the bottom of the jar.

4.1.6. *Post-Experiment Questions*

1. What happened to the egg when placed in B?
   Answer:
   - ✓ The egg sinks and remains at the bottom of the container.
2. What happened to the egg placed in A after adding salt? Why?
   Answer:
   - ✓ The egg floats after salt is added. This happens because the density of the egg becomes less than the density of the salt water.
3. How could we make the egg in A float again?
   Answer:
   - ✓ We could reduce the concentration of salt by adding more fresh water.
4. If you knew the density of fresh water to be 1 g/mL, and the submerged egg displaced 3.5 mL of water, what is the mass of the egg?
   Answer:
   - ✓ The density is the mass divided by the volume of the egg. Thus, if the density is 1 g/mL and the volume is 3.5 mL, the mass is 3.5 g (or density multiplied by volume).
5. Is it possible for a boat designed for the Indian Ocean to sail in Lake Victoria?
   Answer:
   - ✓ Yes, but it will sink more in fresh water (Lake Victoria) than in salt water (Indian Ocean).
6. What factors should be considered when designing and constructing swimming equipment or boats?
   Answer:
   - ✓ Type of water in which the equipment or boat is going to be used (salt or fresh), which informs the density of the water
   - ✓ Weight and volume of the person or boat

4.2. Part II. Heat Transfer & Emission

4.2.1. *Summary*

Students will be able to demonstrate the effect of color on heat emission.

4.2.2. *Pre-Experiment Questions*

1. What are the different types of heat transfer?
   Answer:

- ✓ Conduction (direct contact), convection (movement of heat through fluids in which warmer portions rise and colder portions sink), and radiation (transfer through electromagnetic waves).

2. How do you expect color will impact heat absorption and emission?
   Answer:
   - ✓ Darker colors will absorb more heat (light) than lighter colors, and darker colors will also emit more heat than lighter colors.

4.2.3. *Supplies*

- 1 tin or metal can (half painted black and half painted white or left shiny)
- 2 wooden sticks
- Candle
- Wax (or other very low melting point solid like butter or coconut oil)
- Lighter or matches
- Wood blocks to use as stand

4.2.4. *Procedure (work in groups of 2-4)*

1. Position the wood blocks so that they act like a stand.
2. Place the candle between the wood blocks on the table.
3. Place the metal can on the top of wood blocks with the bottom of the can facing up. The can should be directly over the candle (see Figure 4 for reference).
4. Coat the top of wooden sticks with wax (or other very low melting point material like coconut oil or butter).
5. Place one waxed wooden stick next to the black-painted side of the can and the other next to the white-painted side of the can – both equal distance from the can.
6. Light the candle.

7. Observe what happens to the wax on the wooden sticks.

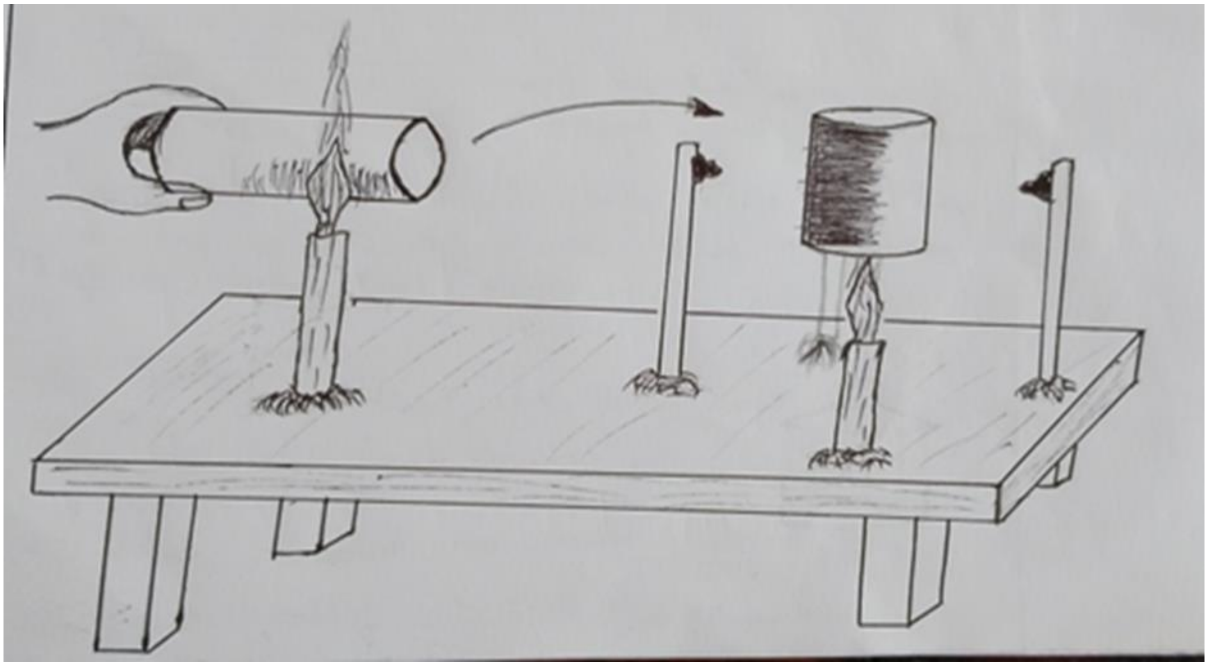

Figure 4. Schematic of the set up with the can (placed upside down) over the candle and two sticks (tops coated with wax) placed equal distance from the sides of the can (right). Instead of painting the side of the can black, you can also use the candle to create soot on one side of the can (left).

4.2.5. *Results*

STICK LOCATION	OBSERVATION	IMPLICATION
Black-painted side	Wax will melt faster on this stick.	Black-painted side is a good emitter of heat.
White-painted side (or shiny side)	Wax will melt slower on this stick.	The white-painted or shiny side is not as good at emitting heat.

4.2.6. *Post-Experiment Questions*

1. What happened to the wax (or other material) on the two sticks? Why did this happen? Use the word "emission" or "emitter" in your answer.
   Answer:

- ✓ The wax on the stick placed closer to the black-painted side melted faster than on the white-painted (or shiny) side. This happened because the black-painted side is a better emitter of heat than the white-painted (or shiny) side.

2. How was heat transferred between the candle, can, and wax (or other material)?
   Answer:
   - ✓ The candle was the source of heat. The heat from the candle was transferred to the can through conduction and convection. The can became hot and then radiated (or emitted) heat that was transferred to the wax.
3. How is heat absorption (through radiation) different than heat emission? How does color matter and what implications does this have in real life?
   Answer:
   - ✓ Heat absorption is the process of taking in heat from the surroundings. This happens when the Sun shines on objects (radiative heating) and they absorb heat. Heat emission is the process of giving off heat to the surroundings also through radiation. Darker colors are better absorbers and emitters of heat. This is why often people in hotter, sunnier climates wear lighter colored clothes and paint their buildings with lighter colors, because lighter colors are better reflectors and poor emitters of heat.
4. What are other areas of life in which heat transfer is important?
   Answer:
   - ✓ There are many possible answers that students may give, including:
     - Design and selection of cooking pots, handles, and utensils
     - Storage and preservation of items you want to keep hot or cold (e.g., through use of Thermos)
     - Electronic devices (e.g., heat sink needed to cool devices)
     - Selection of clothes and paints depending on climates
     - Building construction ventilation
     - Electric heating (e.g., positioning of the heating element)

4.3. Part III. Volcanic Eruption

4.3.1. *Summary*

Students will learn about volcanic eruption and be able to model how this happens using a chemical reaction.

4.3.2. *Supplies*

- Empty plastic or glass bottle (500 ml)

- Vinegar (1 liter)
- Baking soda (2 tablespoons)
- Red food coloring (2 teaspoons)
- Clay soil
- Spoon (for measuring)
- Wood base (40 cm to 50 cm long)

4.3.3. *Procedure (work in groups of 2-4)*

1. Place wood base on table or working bench.
2. Place the 500 mL empty bottle in the middle of the wood (the mouth of the bottle should be pointing upward).
3. Spray or sprinkle some amount of water onto clay soil to make it slightly sticky.
4. Cover the empty bottle with the wet clay soil to model the shape of a mountain (don't cover the mouth of the bottle) (see Figure 5).
5. Measure 400 mL of vinegar and pour into the bottle through the uncovered mouth.
6. Measure 2 teaspoons of food coloring and pour into the bottle containing vinegar
7. Measure 2 tablespoons of baking soda and pour gently into the bottle containing vinegar and food color, then observe what happens.
8. Optional: repeat steps 1-6 for 3, 4, and 5 tablespoons of baking soda (step 7) and record the observation.

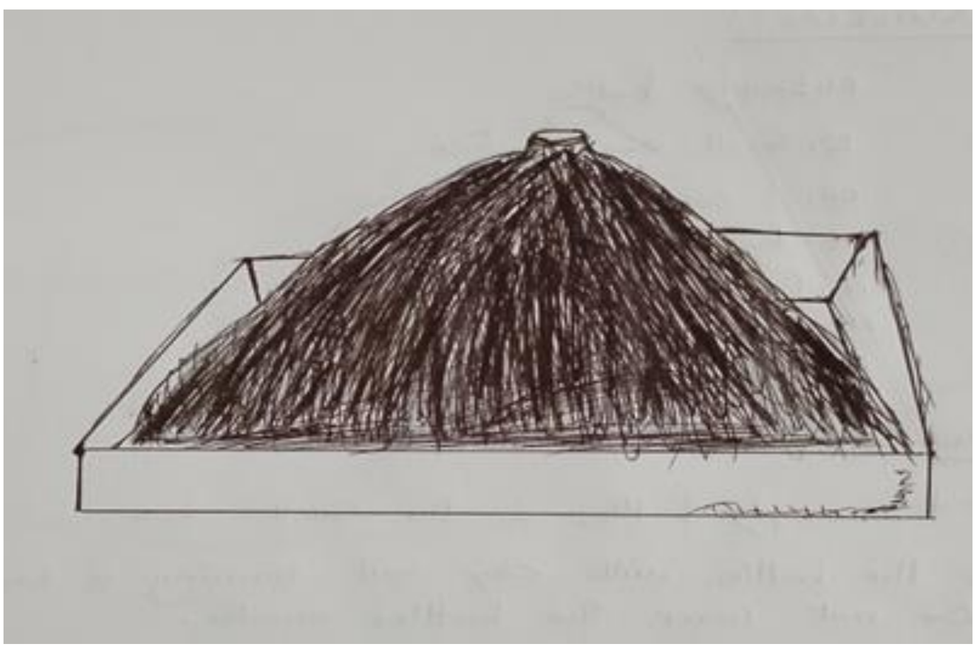

Figure 5. Schematic of volcano model with clay soil surrounding bottle with mouth exposed at top of the structure.

4.3.4. *Results*

EXPERIMENT STEP	OBSERVATION
1. After adding vinegar into empty bottle	No foams sprays out
2. After adding food coloring into bottle containing vinegar	No foams sprays out.
3. After adding baking soda into battle containing vinegar and food coloring	Red foam sprays out the top and down the volcano.

4.3.5. *Post-Demonstration Questions*

1. What happened when baking soda was added into a bottle containing vinegar and food coloring?
   Answer:
   - ✓ A chemical reaction occurred. Vinegar (which contains acetic acid) reacts with baking soda, resulting in the production of gas (carbon dioxide) which escaped from the bottle with liquid in the form of red foam.
2. From the demonstration, what materials represent the Earth's crust, lava, and magma?
   Answer:
   - ✓ Earth's crust – clay soil
   - ✓ Magma – mixture of vinegar, food coloring, and baking soda (below the surface of the volcano)
   - ✓ Lava – red foam that erupted outside the bottle (carbon dioxide bubbles and liquid)
3. How was the model different than and similar to a real volcanic eruption?
   Answer:
   - ✓ The model volcano was different in that a chemical reaction produced the eruption, which is not what happens in a real volcano. The model was similar in that gas and liquid emerge and erupt from below the surface of the volcano (i.e., magma erupts from below the surface of the volcano, becoming lava).
4. In a real volcanic eruption, what are the positive and negative effects?
   Answer:
   There are many possible answers that students could give, including:
   - ❖ Positive effects
     - ✓ Formation of fertile soil

        - ✓ Bringing of valuable minerals to the Earth's surface (e.g., copper, zinc, silver, gold)
        - ✓ Production of geothermal energy (in areas where magma is close to the surface, geothermal energy can be harnessed)
    - ❖ Negative effects
        - ✓ Loss of vegetation and wildlife
        - ✓ Loss of human life and property
        - ✓ Environmental pollution
        - ✓ Damaged landscape
5. What are safety precautions to be taken during real-life volcanic eruptions?
   <u>Answer:</u>
    - ✓ Listen to media (e.g., radio & television) for civil defense advice and follow instructions.
    - ✓ Stay out of designated restricted zones.
    - ✓ Stay indoors as volcanic ash is a health hazard, especially if you have respiratory difficulties such as asthma or bronchitis.
    - ✓ If you have to go outside, use protective gear such as masks and googles and keep as much of your skin covered as possible.

5. Design Challenge

You have learned about Archimedes' principle and various factors that affect the sinking or floating of objects in water. Now it is time to design and construct a boat that can move through water without sinking easily.

5.1 Design Questions

1. What materials would you use to create your boat? Why would you choose these materials? Consider common materials like wood, metal, and plastic, and think about how density matters to keep your boat afloat.
   <u>Answer</u>
   There are many ways students can answer this question. Encourage students to brainstorm different ideas.
    - ✓ Wood, because the density of some types of wood is less than the density of water.
    - ✓ Metal like steel because metal is strong and lasts longer than wood and plastic.

- ✓ Metal is heavy and denser than water, though, so you must make sure there is hollow space in the boat so that the overall density of the boat is less than that of the water.
- ✓ Plastic may be a good option depending on its strength, density, and durability.

2. How could you make your constructed boat float better?

   Answer

   There are many ways students can answer this question. Encourage students to brainstorm different ideas.
   - ✓ By creating more volume within the boat that is hollow space (less dense than water).
   - ✓ By making the boat displace more volume of water.

5.2 Design Sketch

Sketch out your design for your boat in the space below. Be creative!

6. Sources

- TIE (2022), Physics for secondary schools, student's Book form four, TIE, DSM.
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- J.B.A Mihigo et all (1991) Enjoy physics, Mzumbe Book project, Morogoro,Tz.
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