Berkeley Engineers and Mentors

Rain, Go Away

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Field of Interest : Meteorology

Brief Overview In this lesson, mentees will learn about the natural phenomena and processes behind meteorology and storms we see around us. After viewing demonstrations of meteorology concepts such as convection, humidity, and cloud formation, they will learn about how natural phenomena cause thunderstorms to develop.	**Agenda** ● Introduction ● Module 1 : Rising Currents ● Module 2 : Building a Hygrometer ● Module 3 : Cloudy With a Chance of Hairspray ● Module 4 : Waterbending ● Conclusion
Teaching Goals: ● **Convection -** The heat transfer caused by the movements of a liquid or gas; hotter fluids/gasses rise ● **Humidity** - The amount of water vapor in the atmosphere ● **Clouds -** Visible gathering of water droplets and / or ice crystals ● **Static Electricity -** Imbalance of electric charges that remains till discharge ○ **Lightning -** Discharge of electrical charges between clouds and ground	

Mentor Development

Making Concepts Relatable

Most of our mentees are from the Bay Area, where extreme weather events like lightning storms and hurricanes generally don't happen. At site, try to compare real-world meteorological events to scenarios that students may be more familiar with (ex: when you rub your feet on the ground and touch someone else to shock them, that's the same thing as lightning, but on a smaller scale. The people in this example are just like the clouds or ground that the lightning travels between).

Difficult Builds

Some of the builds for the modules may be a little bit difficult for students, especially with delicate tasks like cutting the foil into a triangle in the hygrometer module. This is made even more difficult by the fact that we won't physically be at site to help out. In addition to bringing a finished build to virtual site to show, try to do the build on camera so students can see exactly what to do. In addition, for students at home doing the modules by themselves, make sure to talk about the safety concerns when working with a hot stove and boiling water.

Accessibility

There are several barriers to students' learning, especially in this virtual educational setting. Some students may have learning disabilities; many of them were discussed during the recent MD presentation. Some ways to promote equal access for disabled students include using closed captioning in the curriculum videos that we create, use a variety of teaching methods during site including typing things out in the chat and using hand gestures to explain concepts. You can also refer to the resources from the accessibility presentation. Furthermore, it is also important to be cognizant of factors like race and socioeconomic status that make education and online education harder for people from certain populations. Remember to always be patient with students who haven't had as much experience in the science classroom as others, and continuously consider the factors that give some students an educational advantage over others.

Background for Mentors: Module 1

Module 1

- Convection
- Temperature

Temperature represents the physical quantity of this energy, generally shown with the level of heat. The difference in weight between hot and cold substances is primarily tied to the energy contained by the molecules. Hot air is generally hotter because it absorbs additional energy, causing the molecules to move around more and expand, while cold air is the opposite. Due to this movement, there is more space between molecules, which causes the air to be less dense overall. This is what causes hot gasses and liquids to weigh less than their counterparts. This is specifically seen with liquids and gases, as the molecules for a solid are generally too clustered, so diffusion of matter / flow do not generally occur.

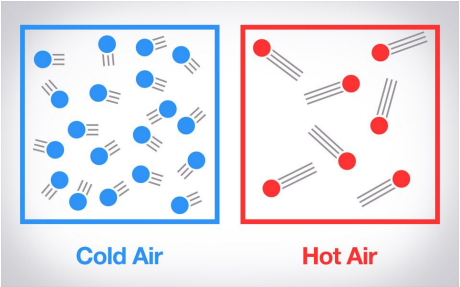

Figure 1 : Cold vs Hot Air

Convection, at its core, refers to the transfer of heat from one area to another. This is usually associated with natural convection, which is a type of flow, where the motion or transfer isn't caused by an external source, but rather the weight of the fluid and / or vapor. This is the cause of the idea that hot air rises and cool air falls, as the cold air is denser. Natural convection occurs commonly in the water cycle, as air near the Earth's surface is generally hotter than air higher up in the air, due to a combination of air pressure, Earth absorbing heat, and several other factors.

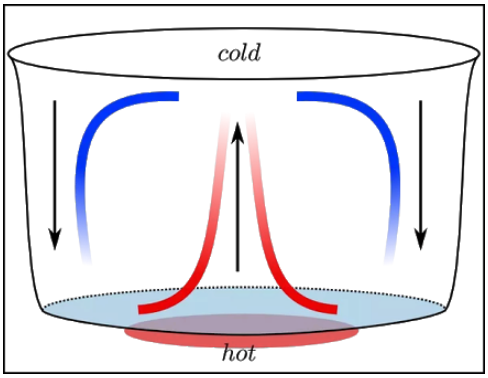

Figure 2 : Convection Diagram

Background for Mentors: Module 2

Module 2

- Humidity
- Relative Humidity
- Absolute Humidity

Humidity refers to the presence of water vapor in the air. Generally, as more water evaporates, the humidity rises. This is why hotter areas generally have higher amounts of humidity. The amount of humidity in the air can be felt through the "wetness" you feel outside. As humidity rises, the air gains more and more moisture, which makes sweat less effective. Usually, the air acts as a sponge in a sense, absorbing the water and heat from sweat, but higher humidity reduces the efficiency of sweat. This is why people generally sweat more in areas with higher humidity.

Humidity is integral to cloud formation, as clouds are composed of water and ice. Generally, areas with more **relative humidity** are more likely rain or snow as the atmosphere is closer to the limit of the amount of water it can hold. For example, if there was 100% relative humidity, then the atmosphere can hold no more water. If more water is evaporated or the temperature goes down, water would be forced out of the clouds, creating precipitation.

Relative humidity refers to the amount of water vapor actually in the air. This is usually expressed as a percentage of the maximum amount of water vapor the air can hold, at the given temperature. So for example, if the air can hold 2 grams of water per cubic meter at the current temperature, and 1.5 grams of water per cubic meter are detected, it would be recorded as 75% humidity.

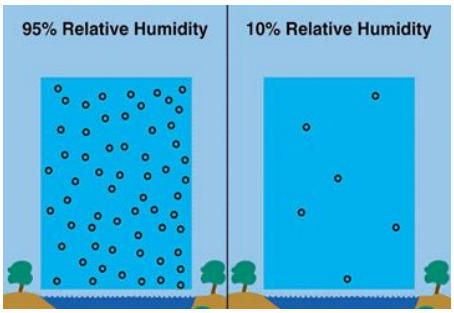

Figure 3 : Relative Humidity Comparison

Absolute humidity, on the other hand, refers to the measure of water vapor in the air, ignoring temperature. This essentially just ignores the temperature, so 1.5 grams of water per cubic meter would just be recorded as that.

Relative humidity is usually considered more important, as it's much more descriptive of the current conditions compared to absolute humidity. For example, a humid but cold location and a dry but warm location could be described to have the same absolute humidity, but could have drastically different relative humidities.

Background for Mentors: Module 3

Module 3

- Clouds
- Evaporation
- Condensation

Many people associate evaporation with convection in the water cycle, claiming that it's due to evaporation that water returns to the sky. However, this is primarily a misconception, as **evaporation** simply refers to the process by which water changes from liquid to gas / vapor. However, the reason the water vapor rises is due to **convection**, as the air closer to the surface is warmer due to air pressure and other factors.

Condensation refers to the process of water vapor transforming back into liquid water due to a drop in temperature. This is an important part of the water cycle and storm formation, as it leads to the creation of clouds. However, condensation can be seen throughout daily life, in the water that drips outside a cold cup, or through the fog on your windshield.

Condensation occurs more at higher altitudes due to a multitude of reasons. Higher altitudes not only have less **Air Pressure**, but also are farther away from the Earth's surface, which absorbs and holds a lot of the Sun's heat. Less air pressure consequently means that the molecules are not being forced to move as much, causing the overall temperature to drop, causing condensation.

Evaporation refers to the process of liquid transforming into a gas due to a rise in temperature. This is important, as evaporation lets water vapor enter the atmosphere. Evaporation rates typically increase in places with less relative humidity, as the atmosphere has more "capacity" for water vapor.

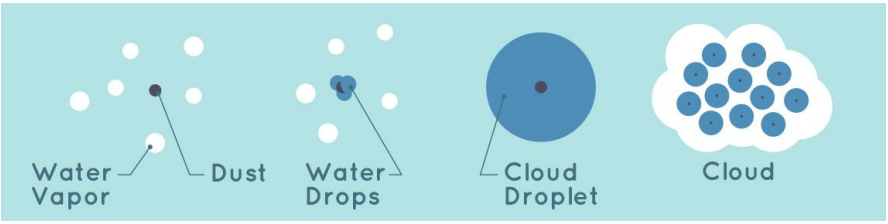

Figure 4 : Cloud Formation

Clouds refer to the tiny liquid water droplets or ice shards that have congregated around tiny dust particles. These particles let clouds form and hold their shape, while allowing more and more particles to gather. As these clouds continue to gather water droplets / ice shards through condensation / freezing, eventually the **weight** of the clouds become too much to sustain. This leads to the precipitation that we're so used to as part of our lives. Precipitation can also be caused partially by changes in temperature.

Background for Mentors: Module 4

Module 4

- Electric Charge
- Static Electricity
- Lightning

Electric Charge is a physical property of matter, usually represented as either positive or negative. This is caused by positive or negative particles that all atoms have, called **protons** and **electrons**. Generally, electric charge follows two rules : Like charges repel each other and unlike attract each other. However, due to the structure of atoms, only electrons can be transferred between atoms.

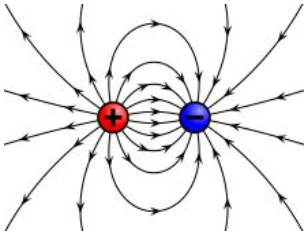

Figure 5 : Electric field of a positive and negative charge

Static Electricity refers to this imbalance of **charges** in atoms. Typically, when we imagine static electricity, a common example is rubbing a balloon against your clothes, and having it stick to walls. This is due to the fact that **electrons** are transferred over when the two objects are rubbed together, creating that imbalance. The shock that we associate with static electricity is the discharge caused by this imbalance. As the electrons stick to an object an imbalance is gradually built. This causes a **discharge** to occur as soon as possible.

Lightning is a large scale example of static electricity. As the little bits of ice in a cloud rub against each other in the air, they start to build up many electric charges, just waiting to discharge. The positive charges form at the top, while the negative charges concentrate in the bottom of the cloud. Lightning occurs when the two charges grow big enough and either spark in the cloud, or down to connect with the positively charged ground.

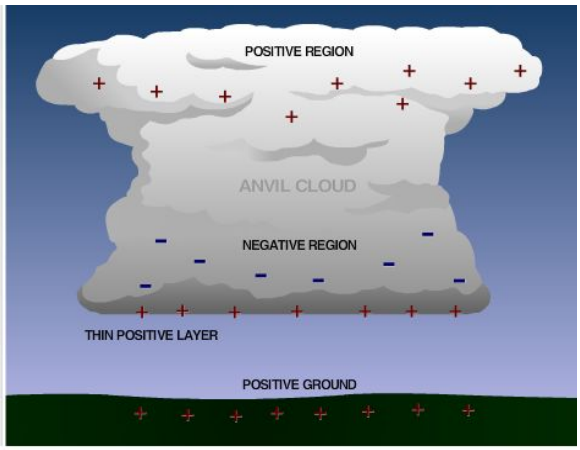

Figure 6 : Charge of a Cloud

Introduction

Meteorology and weather as a whole are incredibly important as they cause the natural phenomena that affect the world around us. Clouds have a huge influence on not only the weather and climate we experience, but also the very temperature of the Earth. As they float above us, they help absorb heat and radiation, while primarily maintaining the water cycle through the storms and precipitation that we've always depended on. By understanding the phenomena above us, we can gain a better understanding of the world around us.

Concepts to Introduce ● Why does it rain and thunder? How are the clouds above us formed? ● Meteorology is the science of the atmosphere, and storms are a huge part of that. ● Water is everywhere, and is core to meteorology as a science. It is constantly being cycled through the planet, and undergoes many state changes throughout. ● We will be focused on how storms are formed in nature, and what they provide for the Earth and its atmosphere	**Current or Past Events** ● Studies on storms can be traced back to early civilizations. Many attempted to predict short-term weather changes, and theorized about the formation of rain, clouds, hail, thunder, and hurricanes. ● Weather forecasting has improved with the spread of communications, as meteorologists can now track weather in different places, allowing us to see weather systems as they move. As models continue to improve, forecasting will continue to advance and become more accurate.
Questions to Pique Interest ● How are clouds formulated, and what are they made of? ● Why does lightning occur? Why do some storms have lightning (thunderstorms) and some don't? ● Why is weather and climate different in different areas of the Earth? ● Why does hot air rise?	**Inspiring Scientists, Careers, Applications** ● Meteorology - The branch of science focused on the atmosphere phenomena, usually for forecasting weather ● Climate Science - Branch of science investigating the structure and dynamics of Earth's various climates

Module 1 : Water Goes Up (Demo)

This module is a DEMO that introduces and explains the concepts of convection and temperature, which allows water vapor to enter and rise through the atmosphere.

Teaching Goals	**Materials**
1. **Convection:** Heat transfer caused by the movements of a liquid or gas; hotter fluids/gasses rise 2. **Temperature:** Measure of the kinetic energy in the atoms of a system, expressed by heat	• Jar • 1 cup of water • Freezer • Mug • Blue Food Coloring • Dropper • Timer

Procedure

1. Prepare a cup of cold water and a cup of hot water ahead of time. The hot water should be significantly hotter than room temperature to perform better.
2. Fill the jar halfway with the cold water.
3. Put it into the freezer for about 5-10 minutes. This will depend on the water's initial temperature and the freezer. Make sure to set a timer, as the water should not get too cold. Room temperature water will also work for the convection.
4. Fill the mug until it's about ¼ full of hot water.
5. Add about drops of the food coloring to the hot water, until it's clearly colored blue.
6. Take the cold water out from the freezer, and let it sit until there are no ripples on the surface from moving it around.
7. Fill the dropper with 2-3 drops of colored, hot water, and then drop them into the bottom of the large jar.
8. Observe the water drops, as they move upwards. Explain how this is due to **convection**, caused by the difference in **temperature**. The hot water should continue to rise, until it reaches the top.
9. Wait, and let the droplet's cool down. As the

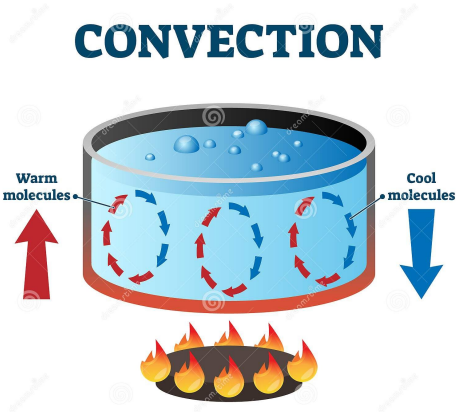

Figure 7 : The Colder water will fall and vice versa

Figure 8 : Drop the blueish water in the bottom of the jar

temperatures normalize, the colored water should drop down as it is now denser.

Notes

As there is hot water in this demo, please be careful. Make sure that the cold water is not actually frozen. Try to drop the water at the very bottom of the jar for the best effect. This may be difficult with larger jars. If the cold water is not working, or time is a limiting factor, you can also use room temperature water.

Module 2: Creating a Hygrometer (DEMO)

This module will explain the concepts of Humidity, which are important towards understanding cloud formation. Mentees will have the chance to see humidity cause a physical change.

Teaching Goals	**Materials**
1. **Humidity**: The amount of water vapor in the atmosphere 2. **Moisture**: Presence of a liquid, especially in small amounts 3. **Relative Humidity:** Measure of the amount of water vapor in the air, relative to the temperature 4. **Absolute Humidity:** Measure of the amount of water vapor in the air, ignoring temperature	• Stick of Gum • Cardboard • Push Pin • Toothpick • Tape • Sharpie / Pen

Procedure

1. If possible, go outside for 3-5 minutes. Once time passes, come back inside. Do you feel any lighter? The **relative humidity** of your home is often significantly lower than the outside air. Higher humidity causes the air to feel more damp and heavy, due to the extra water in the air around us.
2. Take the gum out of its foil wrapper. We will be using the foil wrapper to make the hydrometer.
3. Cut the foil wrapper in a way to make a triangular point, as seen to the right.
4. Use the push pin to create a hole in the cardboard. Make sure that the hole you create can support the toothpick. If the hole is too big, you can use tape to secure it to the cardboard.
5. Wrap 2 inches of tape around the toothpick, and then stab it into the cardboard. This will be used to measure the humidity.
6. Make markings in a circular pattern around the

Figure 9 : Hygrometer setup before spraying

Figure 10 : The tape loosens due to the humidity

toothpick, with the side away from the end of the tape representing high humidity.

7. Breathe out onto the toothpick. The tape should slowly start to unravel. This is due to the water and moisture in our breath. The paper and foil weakens and unravels as it picks up the moisture from the added humidity. As it starts to weaken, it begins to unravel, showing higher **humidity**,

Notes

The humidity inside one's home may depend on the interior heating, and could resemble the outside temperature in certain situations. Additionally, the build demo requires the tape to be loosely wrapped around, to allow the humidity to work on a small section of the tape. This demo can be fairly finicky, so it may be better to just show the video.

Module 3: Cloudy with a Chance of Hairspray (DEMO)

This module will introduce and explain the natural phenomena of clouds. Through an interesting visual demo, mentees will have an opportunity to see the formulation and precipitation of clouds.

Teaching Goals	**Materials**
1. **Clouds:** Visible gathering of water droplets and ice crystals 2. **Evaporation:** Process by which a liquid is converted into a gas, usually through a rise in temperature 3. **Condensation:** Process by which a gas is converted into a liquid, usually through a temperature drop	• 1 glass jar • 1 cup hot water • 3 drops of blue food coloring • Aerosol Hair Spray • 3 pieces of Ice

Procedure

1. Heat the water and make sure that it's still steaming. The explosive rise in temperature will cause the water to **evaporate** extremely quickly. The steam itself represents the formerly liquid water.
2. Put the food dye into the water. This is important, but not necessary, in order to make the cloud extremely visible.
3. Pour the steaming water into the glass jar. Ensure that the water fills about ⅓ of the glass jar.
4. Quickly spray the inside of the jar with the hairspray. Do not spray too much, as the cloud will have trouble forming with too much hairspray. Be sure to do this quickly, as the water must still be steaming for clouds to form.
5. Close the jar. This is important in order to enclose the moisture from the steam. The limited space will have trouble holding the water vapor.
6. Place the pieces of ice on top. This will cause rapid condensation due to the temperature drop. Less water will be able to be contained

Figure 10 : Spray a small amount of hairspray into the jar

Figure 11 : Cloud forms with temperature Difference

in the space as the temperature drops.

7. Watch the jar carefully. A visible **cloud** should form inside the jar. This cloud forms around the hairspray particles, which act similarly to the dust particles in the atmosphere. As the steam / water vapor rises due to **convection**, it hits the cooler top of the jar, causing it to cool down and **condense**. The water vapor condenses onto the hairspray, forming the cloud.
8. Open the jar. The cloud will momentarily hold together, and then rise and disperse, due to the increased space not limiting humidity anymore.

Figure 12: The cloud rises from jar
Due to convection

Notes

Ensure that the amount of water and hairspray in the jar is proportional to the jar's size. Once the lid is put on, the steam inside the jar should "fill" out more and begin to resemble a cloud.

Module 4: Waterbending (ACTIVITY)

This module will introduce the concept of static electricity and charge, and show how these concepts contribute to the natural phenomena of lightning. The mentees will be able to either do an activity to demonstrate the concepts and/or a demonstration depending on the materials / time.

Teaching Goals	**Materials**
1. **Electric Charge** - Property of matter that causes an object to experience a force in response to other charges a. Matter can either have a **positive** or **negative** charge 2. **Static Electricity -** Stationary electric charge, caused by the imbalance of electric charges. **a. Lightning -** A giant spark of electricity caused by static electricity between the clouds and ground. **MD Goals** **written by MD, not applicable for every module** List and explain how to reinforce MD goals during the module.	• Plastic Comb • Sink / Faucet • Hair • Magnet

Procedure

1. Demonstrate **electric charge** by using a magnet. Show how like charges push each other away, and vice versa.
2. Try to think about what you know about electricity, and specifically static electricity. A good example is the famous balloon hair example.
3. Run the plastic comb through your hair fifteen times. Clothing, especially wool can also work as an alternative.
4. Turn the faucet on, making sure that there is only a thin stream running. Try to make the stream as thin as possible.
5. Hold the comb to the side of the stream. The water will bend. This is because water is neutral, while the comb is negatively charged

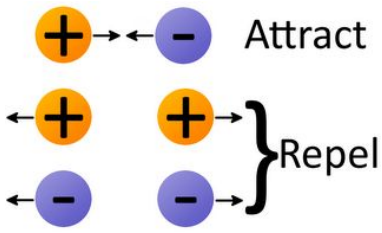

Figure 13 : Opposite charges attract, and vice versa

by picking up electrons from the hair. The water's positively charged particles are attracted to the comb. Lightning is simply this phenomena, on a larger scale. The brushing is replaced by the water / ice particles rubbing against each other.

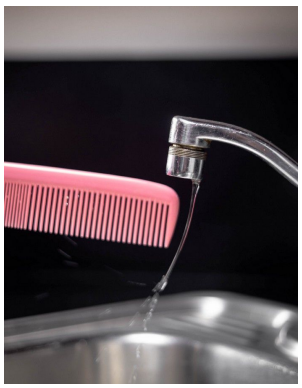

Figure 14 : The water will bend around the comb

Notes

If the student doesn't have the hair necessary for this module, they can ask their family members to do this for them. Fuzzy clothing, such as socks, can also be used for this experiment. Additionally, make sure that the stream of water is as weak as possible.

Conclusion

In order to wrap up the lesson, ask the mentees what concepts they've learned about meteorology, and what other phenomena they're curious about.

References

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Summary Materials Table

	Amount per Site	**Expected $$**	**Vendor (or online link)**
Mason Jar / Clear Glass Jar	1 per site	14.4	Amazon
Water	-		
Food Dye	1 per site	9.88	Amazon
Aerosol Hair Spray	1 per site	4.79	Amazon
Ice			
Push Pins	1 per site		
Tape			

Water Boiler / Stovetop			
Plastic Comb	1 per site	3.49	Amazon
Faucet			
Freezer			
Gum	1 per site		
Cardboard			
Mug	1 per site		
Toothpick	1 per site		
Dropper	1 per site	8.99	Amazon
Magnet			