



The Name's BEAM, James BEAM

Ella Kasamis | Spring '26

Field(s) of Interest: Physics, Chemistry, Biology

Brief Overview (1-3 sentences):

Mentees will be learning the science behind many of the spy gadgets they play with and see on TV. Each module will focus on a different field of science and how each gadget relates to said field.

Agenda:

- Introduction (5 min)
- Module 1: Masking the Message (5-10 min)
- Module 2: Cracking the Code (5-10 min)
- Module 3: Peri the Platypus (15-20 min)
- Module 4: Giving the Goodbyes (5-10 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

→ **Applications of Science**

- ◆ Applying Chemistry
- ◆ Applying Biology
- ◆ Applying Physics

→ Chemical Reactions

→ Fingerprint Analysis

→ Light Waves

Background for Mentors

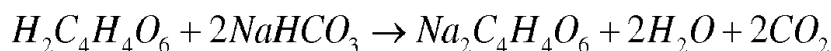
Module 1

- Chemical
- Chemical Reaction
- Acid
- Base
- Acid-Base Reaction

Chemistry is the study of properties of matter and the changes it undergoes. The basis of chemistry is through objects known as **chemicals** which make up our universe. Chemicals are made up of one or more elements, which bond and interact with each other to make solids, liquids, and gasses.

Chemicals are also able to change their properties and elemental makeup through a **chemical reaction**. Unlike a physical reaction, which just changes the form of a chemical, a chemical reaction creates an entirely new chemical through the input or release of energy.

In order to create invisible ink, a specific type of chemical reaction is used, known as an **acid-base reaction**. Grape juice is an **acid**, containing amounts of tartaric and citric acid. This means that grape juice contains hydrogen which it easily gives up. Meanwhile, baking soda (sodium bicarbonate) is a **base**, having a part which easily accepts the hydrogen ion to make water.



Tartaric Acid	Sodium Bicarbonate	Sodium Tartarate	Water	Carbon Dioxide
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Figure 1: Grape juice and baking soda reaction

Grape juice in particular works well in this reaction due to the presence of anthocyanins, a chemical compound which changes color in accordance to pH level. As the acid base reaction occurs, the pH of the grape juice goes from acidic to basic, changing the color of the anthocyanin from purple to a greenish blue.

Colour shift of an anthocyanin

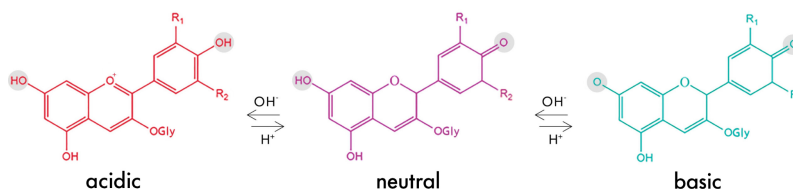


Figure 2: Color changes and structure of anthocyanin

Module 2

- Fingerprints
- Impression
- Latent Prints

Biology is the study of living organisms and their processes. All living creatures and their properties fall under the field of biology, including humans. On a much smaller scale, biology also includes the subfield of genetics, the study of DNA and its related expression.

Each individual's **fingerprints** are unique, allowing for them to be used to identify individuals. This is because fingerprints are formed as a mix of genetic and environmental factors. On one hand, a combination of genes contribute to the specific folding of the skin and the development of muscles and blood underneath, all of which lead to ridges forming. Meanwhile, non-genetic factors such as the prenatal environment also have an impact in ridge development.

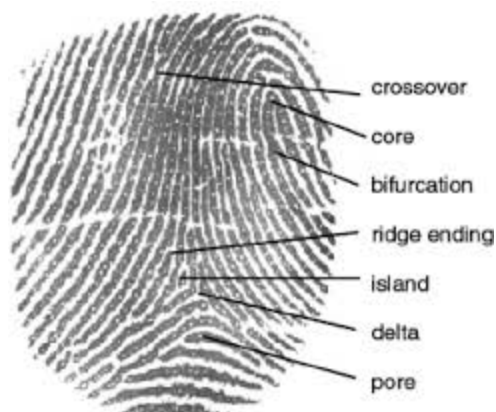


Figure 1: Example of a fingerprint and different shapes within the ridges

Any time our body makes contact with an object, we leave an **impression**, or leftover residue caused by our body's natural oils. Although most impressions are not helpful for identification, our fingerprints are an exception. **Latent prints**, impressions left by our fingers, tend to be high in natural oils, allowing for collection and identification.



Figure 2: latent prints left on a jar, visualized via charcoal

Module 3

- Wave
- Reflection
- Angle

Physics is the study of matter, motion, force, and energy. While chemistry and biology apply physics through reactions, the study of physics looks at the mechanisms behind these functions at the most fundamental level. One of these types of motion and forces physics looks at is known as **waves**. Waves refer to a type of disturbance which repeatedly oscillates along some resting line. Waves can be physical or electromagnetic, with physical waves referring to the traversing through a medium such as air or water. The focus of periscopes, on the other hand, uses electromagnetic waves, resulting in oscillations of electrons to manipulate light.

THE ELECTROMAGNETIC SPECTRUM

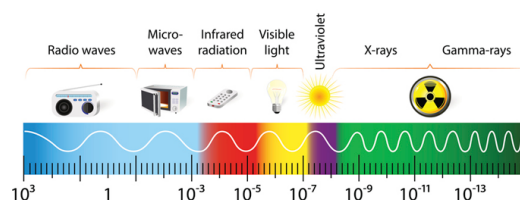


Figure 1: Light is an example of an electromagnetic wave

When waves hit certain matter, they can **reflect** off of that matter. This results in a sudden change of direction. While some objects can only reflect certain types of light, mirrors have the special property of being able to reflect all light, creating highly accurate images which we can see.

When light strikes a mirror straight on, the reflected light will also come straight off of the mirror. However, by changing the **angle** of reflection, we can change the direction in which light bounces off of the mirrors. This is why mirrors can “see” things which are not directly in front of it. In the context of periscope, we make use of this reflection angle to view much higher than we are typically able to see.

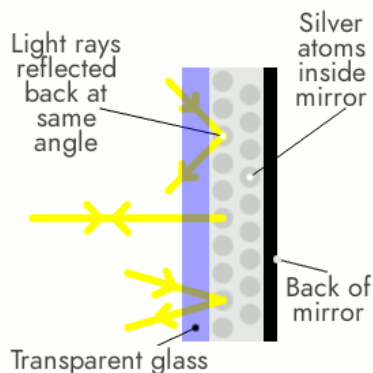


Figure 2: Mirrors reflect light at consistent angles

Introduction

In addition to being a more silly lesson to end off the year, the goal of this lesson is to show how a seemingly less scientific topic has its roots in all fields of the sciences. After this lesson, mentees should be able to connect the fun activities they do outside of school to key scientific topics.

Concepts to Introduce • Applications of science ◦ When working in the context of spy gear, one may not understand its relationship to science, so make sure to highlight the relationship between each scientific field and our gadgets • Wrapping up the year ◦ Use this lesson to connect back concepts to previous lessons, including your final lesson! ◦ Make sure to take time to connect with the mentees, even if it means skipping a module	Questions to Pique Interest • Have you ever tried to sneak a secret message to your friend? • Have you ever used a lock to protect your things? • Have you ever seen a movie where people tried to pull off a heist or sneak into unwanted areas?
Scientists, Current and Past Events • <i>The Zimmerman Telegram</i> is a famous WWI secret message which entailed a possible allyship between Germany and Mexico, but was intercepted by British intelligence (source) ◦ This led the US into WWI as a result • Alan Turing is one of the most famous cryptologists, using his experience code cracking in WWII to eventually found the principles of modern computer science • Lise de Baissac was a highly influential British spy who resided in German-occupied France ◦ Resided next to gestapo ◦ Provided key information necessary for the Normandy landings	Careers and Applications • Forensic Scientist ◦ Experts who analyze evidence left at crime scenes in order to show when and how the crime occurred • Cryptologist ◦ Experts who work on deciphering messages left by foreign groups • Intelligence Officers ◦ Professionals who both protect information and gather enemy information, especially prominent in war

Module 1: Masking the Message

Mentees will be using an acid base reaction to create secret messages using invisible ink!

Teaching Goals 1. Chemical: Any physical item found in our universe, made up of building blocks called “atoms” 2. Chemical Reaction: A way to rearrange chemicals to have new behaviors and properties 3. Acid: A chemical which contains excess hydrogen and often has a sour taste 4. Base: A chemical which contains excess hydroxide (OH) and often has a bitter taste 5. Acid-Base Reaction: A common chemical reaction where the OH of the base steals the hydrogen of the acid to make water (H₂O)	Materials • 1 splash of grape juice per group • 1 scoop of baking soda per group • 1 splash of water per group • 2 cups per group (to hold the liquid) • 1 Q tip per mentee • 1 paper towel per mentee • 1 piece of paper per mentee
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Different Methods for Teaching

1. **Acid:** Prompt mentees to think of acidic/sour things, like lemon juice, vinegar, etc.
2. **Base:** Give some real-world examples of bases, such as baking soda, soap, toothpaste, etc.
3. **Acid-Base Reaction:** You can think of acids and bases sort of like opposites that meet and balance each other out (like hot and cold water)! You can also mention real-world examples, like how toothpaste (basic) protects our teeth from acids in our mouth.

Procedure

1. Give each mentee a piece of paper and a paper towel, placing the paper on top of the towel
2. At each group, place a small scoop of baking soda in one of the cups. Add water to the same cup and mix
3. Have each mentee use one side of the Q tip to write or draw their message
 - a. It can take some time for these messages to fully dry, so I recommend moving on to the next activity while they are drying
4. **After the messages have dried,** add a *small* splash of grape juice per group



Figure 1: Use a very small amount of liquid in each cup to avoid spilling

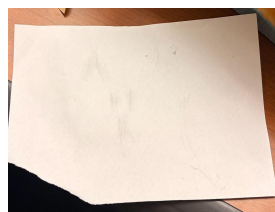


Figure 2: Once dried, the message should be mostly invisible to the naked eye

5. Have mentees use the other side of their Q tip to *lightly* brush grape juice over their drawing
6. Watch the message get revealed!

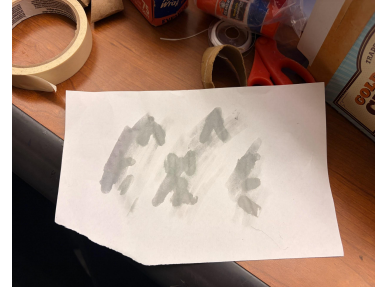


Figure 3: *Lightly spread grape juice over to reveal the secret message*

Classroom Notes

- Be light on the grape juice!
 - You can see in Figure 3 where I used too much, messing with the result
- Make sure the paper is on top of the paper towel to prevent stickiness

Module 2: Cracking the Code

Mentees will be unearthing prints in order to crack a secret code.

Teaching Goals

6. **Fingerprints:** Unique patterns found on the front of our fingers
7. **Impression:** Any residue left when our body comes into contact with an object
8. **Latent Prints:** Hidden impressions made by our the oils on our fingers which can be used to identify individuals via matching fingerprints

Materials

- 1 printed paper per group
- 1 plastic sleeve per group
- 1 whiteboard marker per group
- 1 paintbrush per group
- 1 scoop of cornstarch per group
- 1 bottle of lotion per site

Different Methods for Teaching

4. **Fingerprints:** Think about other things that have a unique pattern (snowflakes, trees, etc.). You can also think about why touch-id passwords work (because each person's fingerprint is unique).
5. **Impression:** Impressions are made all the time! Think of tire marks, shoe prints, snow angels, etc.

Procedure

7. Each group will receive their "safe"- a printed piece of paper within a plastic sleeve
8. The mentor in charge of each group will write four possible number combinations for the mentees to choose from
 - a. Note: try to make each combination have four unique digits (e.g. 1357 NOT 1333)
9. The mentor will put a small amount of lotion on their finger (mimicking our natural oils), then secretly input the code
10. The mentees will then take a small scoop of cornstarch and put it on the plastic
11. Have the mentees use the paintbrush in a light, sweeping motion to dust for prints. The cornstarch will attach to the lotion, revealing the code



Figure 1: Insert this printout into the plastic sleeve and input the four digit code

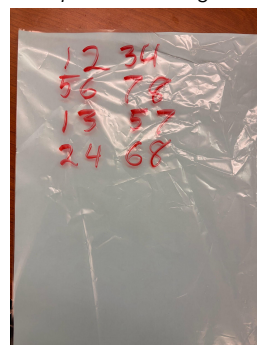


	Figure 2: Write 4 possible code combinations for mentees to guess  Figure 3: Dust away cornstarch in order to reveal the fingerprints on the printed sheet
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Classroom Notes

- This module can get messy! Feel free to reuse paper towels for corn starch cleanup

Module 3: Peri the Platypus

Mentees will be using mirrors to check unlikely places.

Teaching Goals

9. **Wave:** A disturbance which carries energy from one place to another
10. **Reflection:** The changing of direction of a wave via some object
11. **Angle:** The measure of how much an object rotates, with one full rotation equaling 360 degrees

Materials

- 2 small pieces of slitted cardboard rolls per group
- 1 large piece of slitted cardboard roll per group
- 2 mirrors per group
- 1 roll of tape per group

Different Methods for Teaching

6. **Wave:** There's so many different kinds of waves all around us! Everything from how sound travels to you to lights and electromagnetic waves are all types of waves.
 - a. An example of how waves carry energy is if two people hold a rope standing still and one person gives it a shake, you can see the wave in the rope (aka. the energy) travels all the way to the other person.
7. **Reflection:** When you look at your reflection in the mirror, the light waves bounce off the mirror to your eyes. Thus, when you look at your reflection from different angles, the image you see can distort.

Procedure

12. Take the large cardboard roll and one small cardboard roll and line it up so that they meet at a 90 degree angle
 - a. The slits on each roll should be aligned
13. Tape the outside of the rolls together, leaving room for mirrors to be added through the slit
14. Repeat the previous two steps for the other side of the roll
15. Take the plastic film off of the mirrors if they appear cloudy
16. Insert the mirrors at 45 degree angles. You should be able to both see the mirror's reflection and have it reflect downwards
 - a. You can adjust this further using your finger or a marker to get the exact spot
17. Tape the slits of the cardboard closed
18. Look at the reflection outwards!



Figure 1: Example of the slit in the smaller cardboard piece

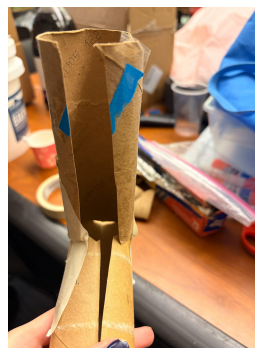


Figure 2: Connect the two cardboard pieces at 90 degree angles, aligning the slits



Figure 3: *Insert the mirrors at 45 degree angles*



Figure 3: *Final product*

Classroom Notes

This module is very technical! Discuss beforehand with your site members if you'd like to have one person demo the activity together with other mentors helping around or if you'd like to split up into groups and demo/help your own group.

Module 4: Giving the Goodbyes

Two optional activities are available to wrap up our last lesson of the year! The first is a combination of all past 3 modules, and the second is a more laid back Q&A session.

Teaching Goals 12. None!	Materials 1 piece of candy per mentee
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Different Methods for Teaching

- 8. Incorporate Teaching Goals:** Throughout Activity 1, mentors can help connect teaching goals with the fun activity they are doing and how it might be used in real life!
 - a. ex. Periscope → reflection → help you see areas you might not be able to see naturally, like car side mirrors
- 9. Have fun!!** Happy last site! Thank you all for a great semester of sites 😊 Feel free to take a picture, answer lots of questions, encourage curiosity, and enjoy!
- 10. Sad Tears:** If a mentee begins to cry or says they'll miss you, feel free to give them a big hug and let them know BEAM will be back. Though you may not be their mentor, mentees will be able to meet your other amazing mentor friends in BEAM and learn more fun STEM lessons!! 🥰

Procedure

Activity 1:

19. Only do this activity if you have a fast moving class, as it might take a bit of preparation
 - a. This can be done one per class or one per group depending on the class size
20. During the first module, use the invisible ink to write 4 codes on a piece of paper
21. Hide the paper somewhere in the classroom, ideally someplace high up
22. After the mentees complete their periscopes, inform them of this secret paper and let them search for it
23. While they are searching, input one of the four codes on the plastic sheet
24. Mentees will have to use the grape juice to reveal the possible codes, then dust for fingerprints in order to “crack open the safe”
25. If they successfully solve the code, reward them with candy!



Figure 1: Everyone having a happy time ending the year together :)

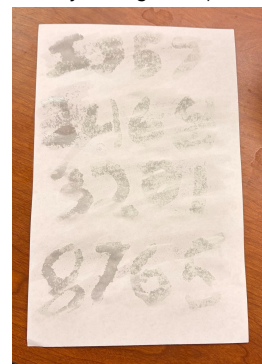


Figure 2: 4 possible codes written and revealed through invisible ink

<u>Activity 2:</u>	
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| <ol style="list-style-type: none">1. Use this time to answer any questions mentees have about life, college, or science!2. Feel free to use this time to go outside, reward candy for such a fun semester, etc. | |
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Classroom Notes

- If you choose option 1, please plan ahead! The ink can take a bit to dry and turn invisible

Conclusion

After spending some time with your mentees, celebrate having a fun semester of learning! Reflect back on some of your favorite moments, and be sure to share pictures.

References

- <https://youtu.be/yltH9wyF8YA?si=xMWtNsRxNXLzzl3M>
- <https://www.youtube.com/watch?v=B5NCqIBM34o>

Summary Materials Table

Material	Amount per Site	Expected \$\$	Vendor
Grape Juice	1 cup		
Q Tips	~20	4.49	Amazon
Baking Soda	1 cup		
Cups	10		
Paper Towels	~20	6.97	Amazon
White Paper	~20	6.97	Amazon
Water	1 cup		
Printed Paper	5		
Plastic Sleeve	5	4.99	Amazon
Cornstarch	1 cup		
Paintbrush	5	6.59	Amazon
Lotion	1	6.99	Amazon
Paper Towel Rolls	10	27.99	Amazon
Tape	3		
Mirrors	10	13.99	Amazon
Candy	~20	23.84	Amazon

Whiteboard Marker	5	8.99	Amazon
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