



Don't Get Burnt

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Target grade: 10th-12th grade physical science

Time required: 2-3 days (1 day for writing lab reports)

Standards

Next Generation Science Standards (NGSS):

- HS-ETS1-1: Analyze complex real-world problems by specifying criteria and constraints for successful solutions.
- HS-PS4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

Lesson Objectives

Students will be able to:

- Define wavelengths and types of radiation.
- Describe mechanisms of light absorption and reflection.
- Compare the efficacy of different sunscreen products by testing them.

Central Focus

Whether it be living in a sunny place, vacation, or just laying on your porch tanning in the summer, students are constantly being exposed to the sun's harmful radiation. In this lesson, students will learn how they can protect themselves against the harmfulness of ultraviolet (UV) radiation and interactions of light. Students will learn the basic properties of waves and light. Students will work together in small groups of three to four and practice using the scientific method to create a methodology that tests the effectiveness of different sunscreens to protect people from ultraviolet radiation. Students will use UV beads and expose them to UV light to determine the level of exposure through each different type and SPF level of sunscreen.

Key terms: absorption, physical science, chemistry, physics, photon, SPF, electromagnetic



Background Information

Students should have some understanding of UV radiation, as well as its harmful effects. UV radiation is a form of electromagnetic radiation that comes from the sun and man-made sources such as tanning beds and welding torches. Higher-energy UV rays are a form of ionizing radiation which means that they have enough energy to remove an electron from an atom or molecule. Ionizing radiation can damage the DNA in cells, which may lead to cancer. UV rays do not have enough energy to penetrate deeply into the body, so their main effect is on the skin. Hence, the solar beads change color depending on the energy, frequency, and wavelength of the light wave.

This lesson covers the photoelectric effect, which is a challenging topic. This topic requires students to be familiar with the following:

- Parts of an atom: electrons, protons, and neutrons
- Bonds between atoms

Photoelectric effect is a phenomenon whereby electrically charged particles are released from or within a material when it absorbs electromagnetic radiation.

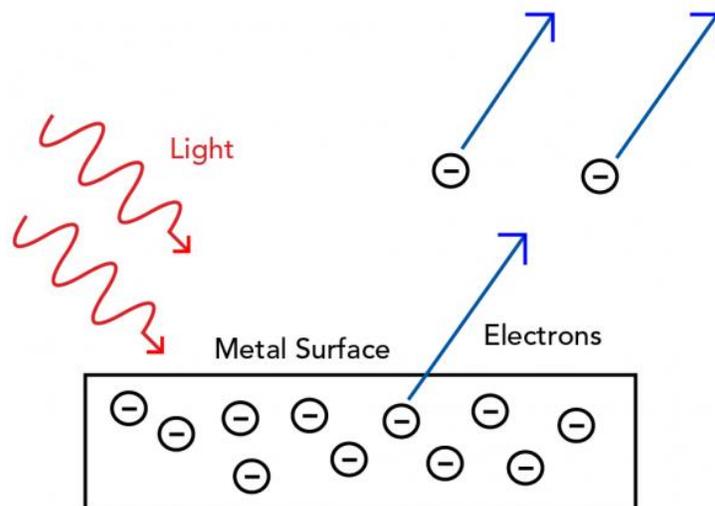


Figure 1: <https://letstalkscience.ca/educational-resources/stem-in-context/introduction-quantum-mechanics>

Students must be familiar with performing experiments and the scientific method. They must already know what a control is in an experiment.



Students will be introduced to the following vocabulary:

- Waves: disturbances that carry energy through matter or space.
- Transverse waves: motion is perpendicular to the particle motion
- Longitudinal Waves: motion is parallel to the particle motion
- Reflection: bounding of wave when it hits a boundary
- Diffraction: bending of waves
- Refraction: when waves travel into another medium

Materials

- White boards and markers (one of each per student)
- Different types of sunscreen including generic and brand names and different SPF's of both
- Cotton swabs (several per group)
- UV beads (can be purchased)
- 5" x 8" index cards (one per group)
- UV light source
- Double sided adhesive tape
- Computer
- LCD projector
- Slinky (enough for each pair of students)
- Padlet ([Padlet: You are beautiful](#))

Instruction

Day 1

Introduction (10 minutes)

- Begin with a think, pair, share by asking the class what they know about waves. Have the students discuss the question with a partner and share once most pairs are done discussing.

Example questions to ask:

- What are examples of waves? Can you always see waves?
- How about microwaves? What are those waves?

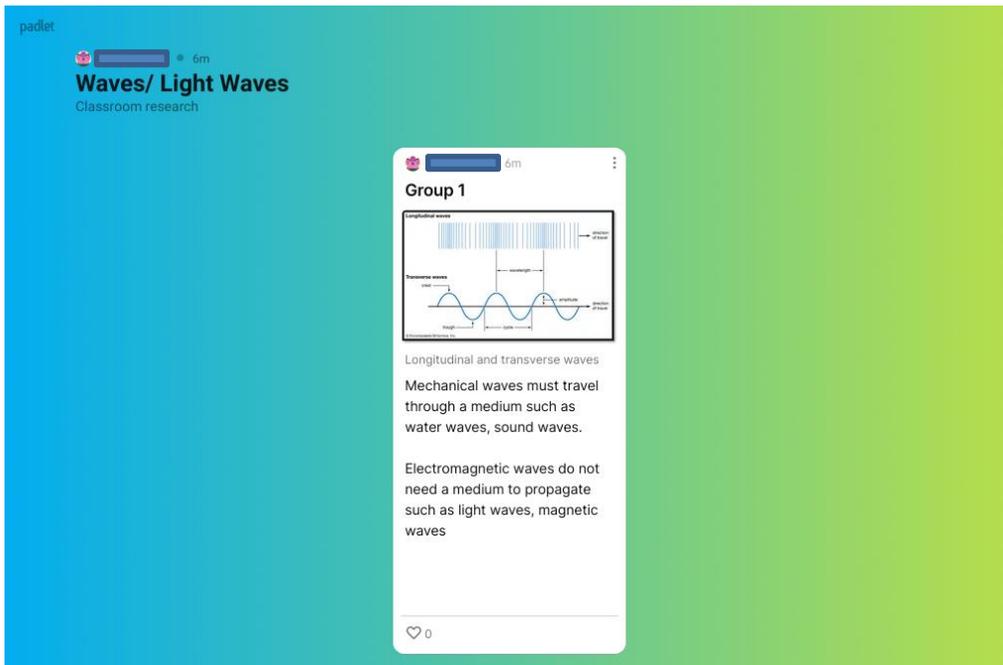
Research (35 minutes)

- Have students in groups of 3 or 4 define or find images related to each term: **waves, mechanical waves, electromagnetic waves, longitudinal waves, traverse waves, period, frequency, electromagnetic spectrum, wave-particle duality, photoelectric effect** (see attached presentation slide 2). The students will post their definition or image, or both, on one padletboard, but each group can post as many posts as they need.



- Padlet is a website where a board can be created, so that students can collaborate or see their peers' ideas and/or thoughts.

- Students will learn about the following terms:
 - ❖ Waves, both mechanical and electromagnetic
 - Waves are disturbances that carry energy through matter or space
 - Mechanical waves must travel through a medium such as water waves, sound waves
 - Electromagnetic waves do not need a medium to propagate such as light waves, magnetic waves
 - ❖ Longitudinal and transverse waves
 - Longitudinal waves are waves that have motion which is parallel to the particle motion such as earthquakes or sound waves
 - Traverse waves are waves that have motion which is perpendicular to the particle motion such as a guitar string, “the wave” in a sports stadium
 - ❖ Wave properties
 - Period is the time it takes for one wavelength to pass a point
 - Frequency is the number of wavelengths that pass a given a point/ 1 second
 - ❖ The electromagnetic spectrum
 - This is the range of wavelengths or frequencies over which electromagnetism extends
 - ❖ Wave-particle duality, the photoelectric effect
 - Wave-particle duality is the idea that light has properties of both light and particles
 - Photoelectric effect is the emission of electrons when electromagnetic radiation hits a material



- Once the students, post their definitions or pictures on padlet, briefly go through the terms on slides 3-7.
- On slide 4, ask for two student volunteers. These students will come to the front of the room and use a slinky to illustrate the difference between longitudinal and transverse waves, as well as different frequencies and wavelengths. Have other students pair up and demonstrate the different types of waves.
 - This visual demonstration can help students see the difference between longitudinal and transverse waves. Depending on the speed and the strength of the force that one student implements on the slinky, the frequencies and wavelengths will change.

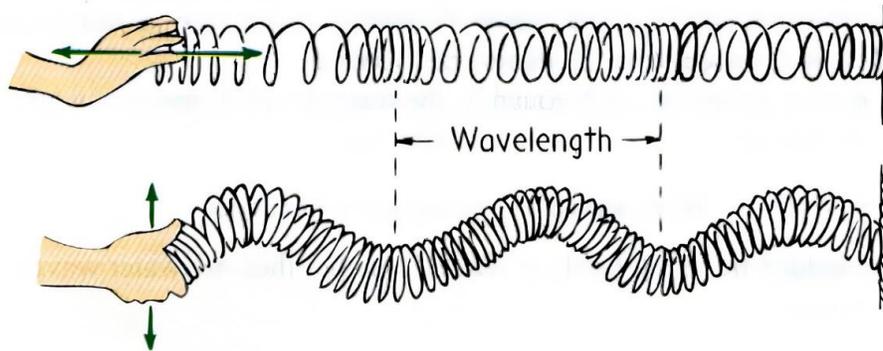


Figure 2: <https://www.kidzworld.com/article/21301-science-project-idea-amazing-natural-disasters-earthquakes>

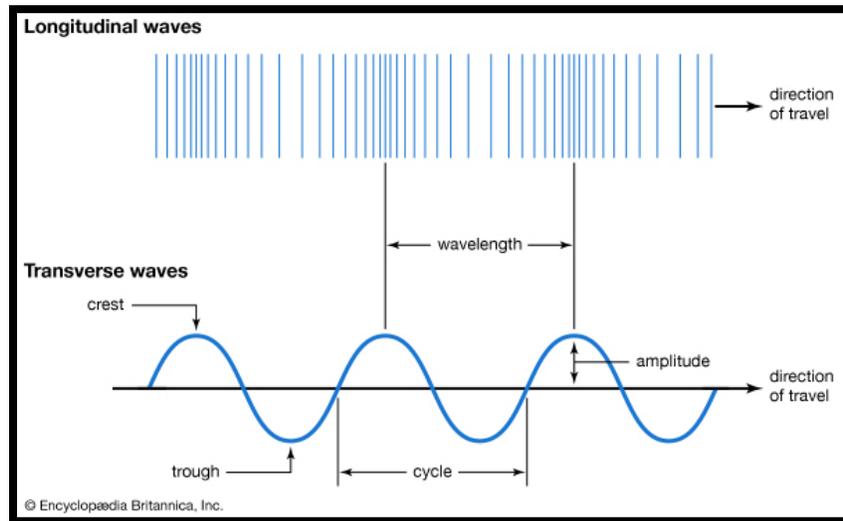


Figure 3: <https://kids.britannica.com/students/assembly/view/53868>

- The teacher will explain and walk through slides 8-15. Slides 8-15 focus on specifically the light wave. Students will learn about wave interactions: reflection, diffraction, and refraction as well.
 - ❖ Reflection is a bouncing of wave when it hits a boundary.
 - ❖ Diffraction is a bending of waves.
 - ❖ Refraction is when waves travel into another medium.



Closure (5 minutes)

- As an exit ticket, have students write on their whiteboards one thing they learned today. The teacher can check what they wrote and then dismiss them.

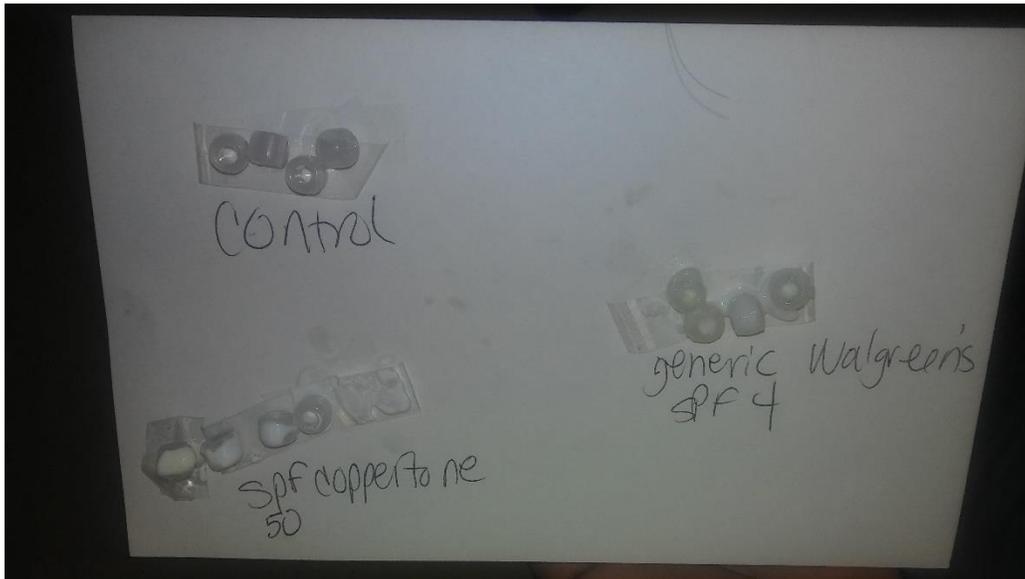
Day 2

Introduction (5 minutes)

- The class will review how light is a wave and a particle. Ask the class, “Can you explain the wave-particle duality and the photoelectric effect of light?”
- Then the class will review slide 13, which explains how sunburns happen.
- The teacher will explain how the class will conduct experiments to test how efficient different sunscreens are at blocking or absorbing UV radiation.
- The teacher will explain the lab report and what will need to be included.
 - ❖ Students can complete the lab report in groups or partners.
 - ❖ Sections that need to be on the lab report (see lab report template below):
Heading, Title, Problem, Hypothesis, Materials, Procedures, Data, and Conclusion

Explore (40 minutes)

- Brainstorming with the students, the class will discuss different methods to test the effectiveness of sunscreens using the materials provided. Make sure the students understand that the solar beads change color when exposed to UV light.
 - ❖ Ideas will be written on the classroom board.
- Once various strategies are discussed, the class will be broken into small groups of 3-4 students. Each group will develop a hypothesis and design a procedure to test the effectiveness of different sunscreens. Make sure the students identify and use a control group.
- After getting approval from the teacher, they can begin to test their procedure. This is an open-ended inquiry investigation.
 - ❖ For example, one group will place 12 beads onto a piece of cardboard with tape into 3 groupings. One set of 4 beads will act as the control. In another set of 4 beads will be tested using a generic brand of sunscreen, while another set of name brand sunscreen will be used on the last 4 set of beads (see example below).
 - ❖ If beads are not adhering to tape, place in snack sized baggies or in plastic petri dishes.



- Students following their protocol can either use sunlight or a UV light to place their beads under for their prescribed amount of time.
- The students will record their results, draw illustrations, and take pictures using their cellphones. (See sample results in the attachments below.)
- The group will discuss their findings and draw conclusions. If needed, they may have to modify their hypothesis and/or procedure.
- Closure (5-10 minutes)
 - At the end of this lesson, students will share their results with the class in an informal discussion.
 - Instruct students to complete a lab report by a given due date.
 - ❖ Lab report will be scored by the rubric attached below.
 - ❖ Teacher may decide if lab report template is given to students.

Differentiation

- English Language Learners:
 - Allow students to work with an upper-level partner throughout the experiment.
 - Provide students with a vocabulary sheet that contains pictures of each term and a copy of the presentation in their language.
 - Allow students to use online translators.
- Students with disabilities:
 - Group students intentionally with others that can support them.
 - Give extra support during the group experiment.
 - Ask these students questions during the group work to make sure they understood the material from the presentation.
 - Give these students a structured template on which to complete the lab report.



- Advancement:
 - Give students sunscreen without labels so that they must figure out the SPF rating of each kind.
 - Have students complete further research into either the dual nature of light or how it changed physics or the chemical makeup of sunscreen that absorbs UV radiation.
 - Ask students to research what situations require that light be a wave and what situations require it be a particle and make a table.
- Grouping:
 - Students could be grouped in ways that have varied levels in each group. This can help the students collaborate with each other. With different levels in a group, students can help and support each other, especially with the research and the experiment.
- Timing:
 - For the students who finish early, have them reflect back on the lesson and vocabulary in their own words.
 - For the students who are slower, since the students are in their groups for the majority of the time, the workload could be divided for timing purposes.

Assessment

Formative Assessment:

- The teacher will check for understanding through classroom discussion. The teacher will help facilitate discussion and correct misconceptions, if necessary.
- The exit ticket at the end of the first lesson will help gauge student understanding.
- The opening discussion on the second day will allow the teacher to check for understanding of the material as well as the end of class discussion about the experiment results.

Summative Assessment:

- The teacher will score students on completion, accuracy, and participation through the lab report rubric. Guiding Questions to be assessed in lab report:
 - Which sunscreen worked the best?
 - Did you see a difference in the ability of the different products to block UV light? Is it related to the SPF factor on the label?
 - Do you think a thicker layer of sunscreen would affect the results?
 - How could UV rays be harmful to the human skin?
 - How does chemical sunscreen protect the wearer? Explain in detail.

Lab Report Evaluation Form

Student Name: _____

Title of Experiment: _____

Date Submitted: _____

Lab Partner(s): _____

Criteria	0	1	2
Heading, Title, Problem, and Hypothesis	Most of the criteria are not clear and not appropriate.	More than half of the criteria are clear and appropriate.	All of the criteria are clear and appropriate.
Materials	None of the materials are listed.	Some of the materials are listed.	All materials are listed.
Procedure	The summary of the procedure is poorly written.	The summary of the procedure is somewhat well written.	The summary of the procedure is well written.
Data	The results and observations of the data are poorly written using a chart, graph, or drawing.	The results and observations of the data are somewhat written using a chart, graph, or drawing.	The results and observations of the data are clearly written using a chart, graph, or drawing.
Conclusions	Conclusion is not clear and concise.	Conclusion is somewhat clear and concise.	Conclusion is clear and concise. Answers the question: "How could I further support my data?" Includes the section: "This is what I learned/observed, these are possible sources of error, this is what could improve my research."
Neatness, Grammar, and Format of all sections.	Lab report is messy, poor grammar, and/or sections are missing.	Lab report is somewhat neat, some grammatical errors, and all sections are present.	Lab report is neat, little to no grammatical errors, and all sections are present.

Teacher Comments:

Criteria	0	1	2
Heading, Title, Problem, and Hypothesis	Most of the criteria are not clear and not appropriate.	More than half of the criteria are clear and appropriate.	All of the criteria are clear and appropriate.
Materials	None of the materials are listed.	Some of the materials are listed.	All materials are listed.
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Neatness, Grammar, and Format of all sections.	Lab report is messy, poor grammar, and/or sections are missing.	Lab report is somewhat neat, some grammatical errors, and all sections are present.	Lab report is neat, little to no grammatical errors, and all sections are present.

Initial of Student grader: _____

Student Comments:

LIGHT

and waves

Define Terms

- Use the internet to find the definition or picture(s) related to these terms: waves, mechanical waves, electromagnetic waves, transverse, longitudinal, wave properties (period, frequency), electromagnetic spectrum, wave-particle duality, photoelectric effect
- Go to <https://padlet.com>
- As a group, post the definitions or pictures.

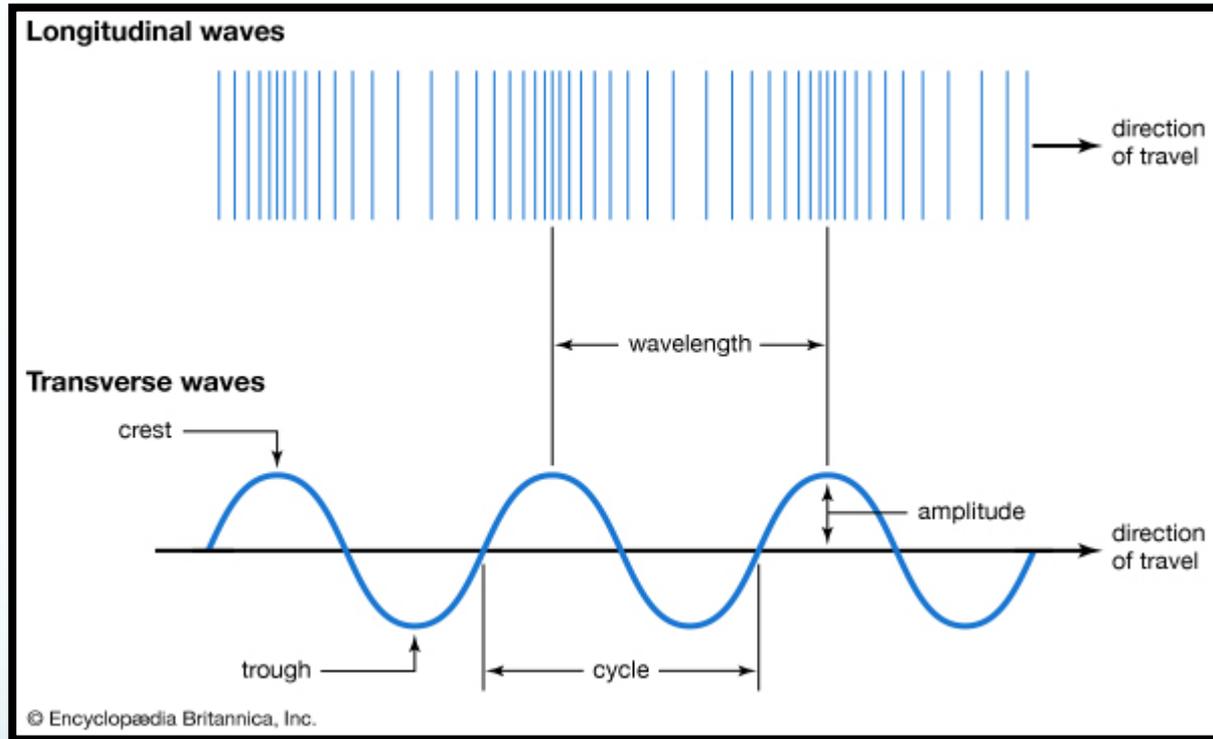
WAVES

- Def: Waves are disturbances that carry energy through matter or space.
 - Mechanical waves must travel through a medium.
 - Water waves, sound waves
 - Electromagnetic waves do not need a medium to propagate.
 - Light waves, magnetic waves
 - Waves transfer energy, not matter.
 - Most waves are caused by vibrating objects.

Types of waves

- Transverse- motion is perpendicular to the particle motion
 - Guitar string, “the wave” in a sports stadium
- Longitudinal-motion is parallel to the particle motion
 - Earthquakes, sound waves
- Surface waves are a combination of both types.
 - Water waves

Characteristics of waves



<https://kids.britannica.com/students/assembly/view/53868>

Characteristics of waves

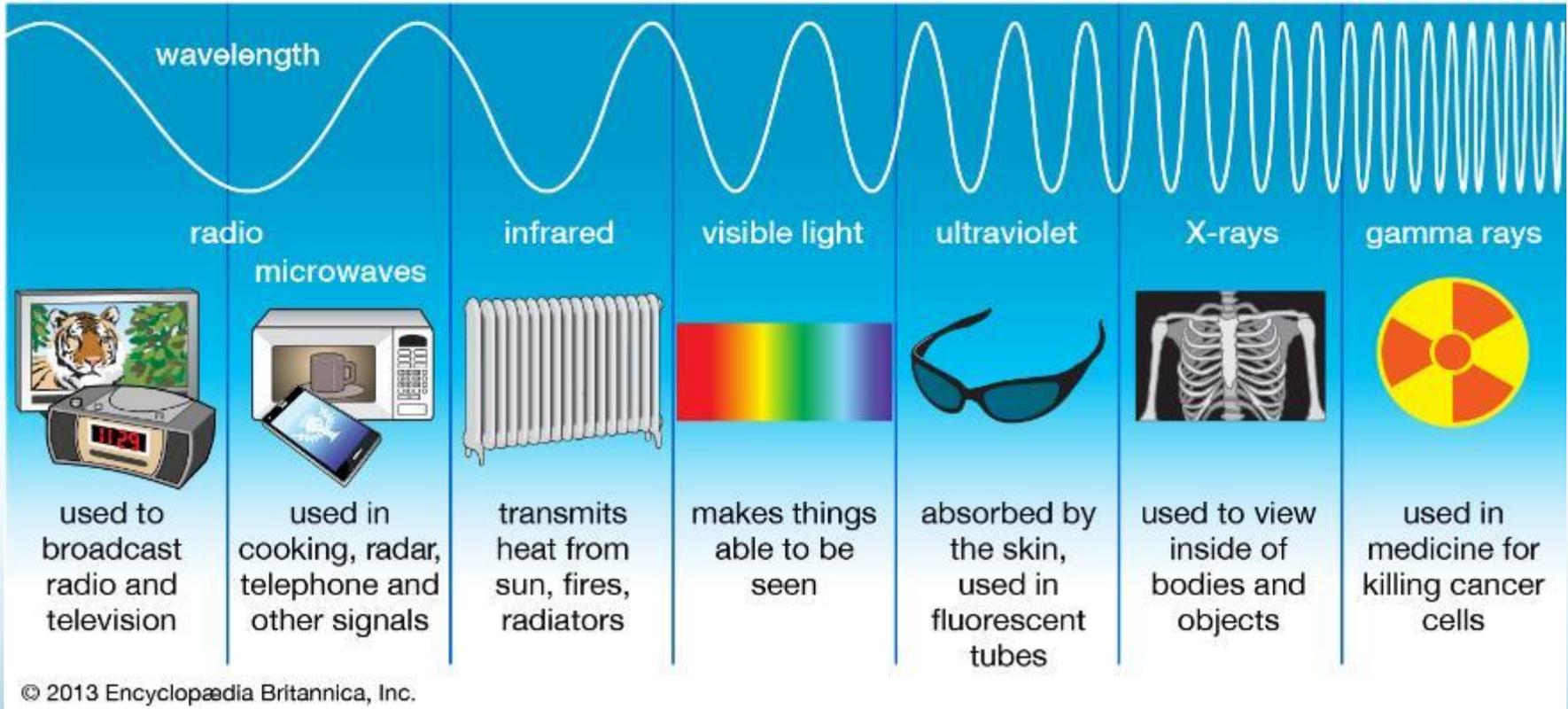
- A wave's period is the time it takes for one wavelength to pass a point.
- A wave's frequency is the # of wavelengths that pass a given point/1 second
 - Measured in hertz

Frequency= $1/\text{period}$

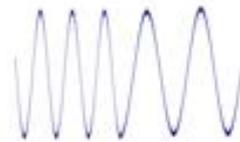
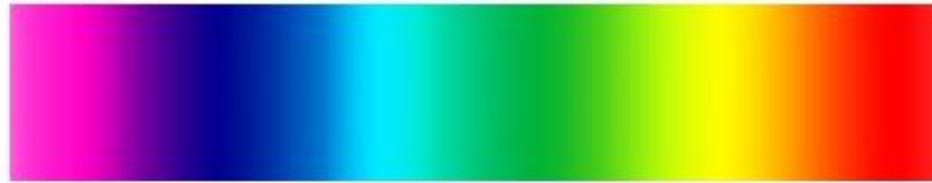
Wave speed= $\text{wavelength}/\text{period}$ or $\text{frequency} \times \text{wavelength}$

Electromagnetic Spectrum

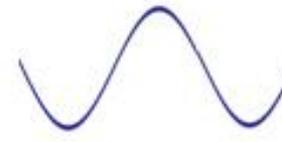
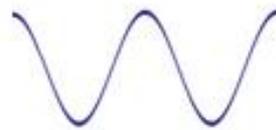
Types of Electromagnetic Radiation



The Visible Spectrum



high frequency



low frequency

Red, orange are longer wavelength, lower frequency, lower energy colors.

Blue and violet are shorter wavelength, higher frequency and higher energy colors.

Wave Interactions

Reflection- bouncing of wave when it hits a boundary

Diffraction- bending of waves

Refraction- when they travel into another medium

SPEED DEPENDS ON MEDIUM

- Waves travel faster in liquids and solids than in gases.
- Light has a finite speed.

LIGHT

There are two common models of light:

1. Light can be modeled as a wave.

This model describes light as transverse waves that do not require a medium in which to travel.

Light waves are also called *electromagnetic waves*.

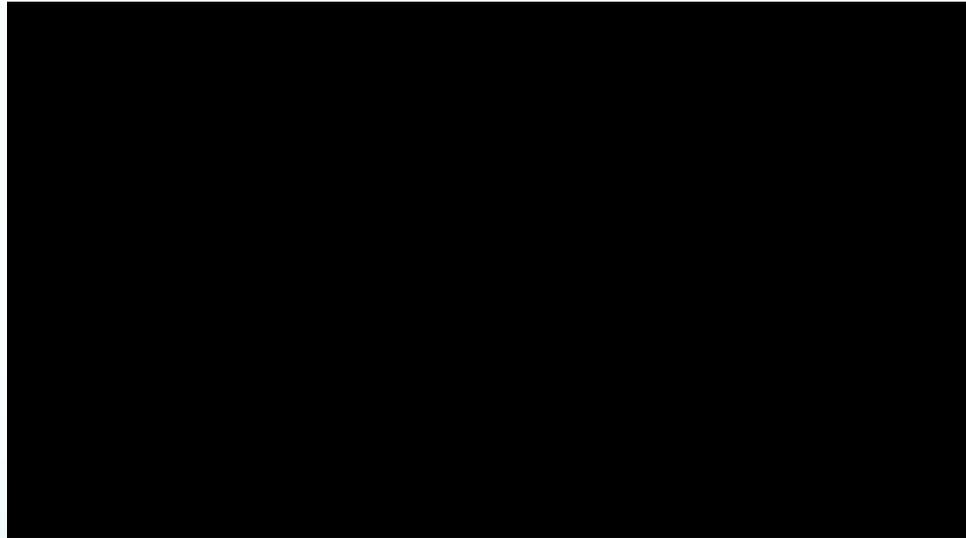
They consist of changing electric and magnetic fields.

LIGHT

2. Light can be modeled as a particle.

- In the particle model of light, the energy of light is contained in packets called photons.
- **photon: a unit or quantum of light**

The Photoelectric Effect



<https://www.youtube.com/watch?v=MFPKwu5vugg>

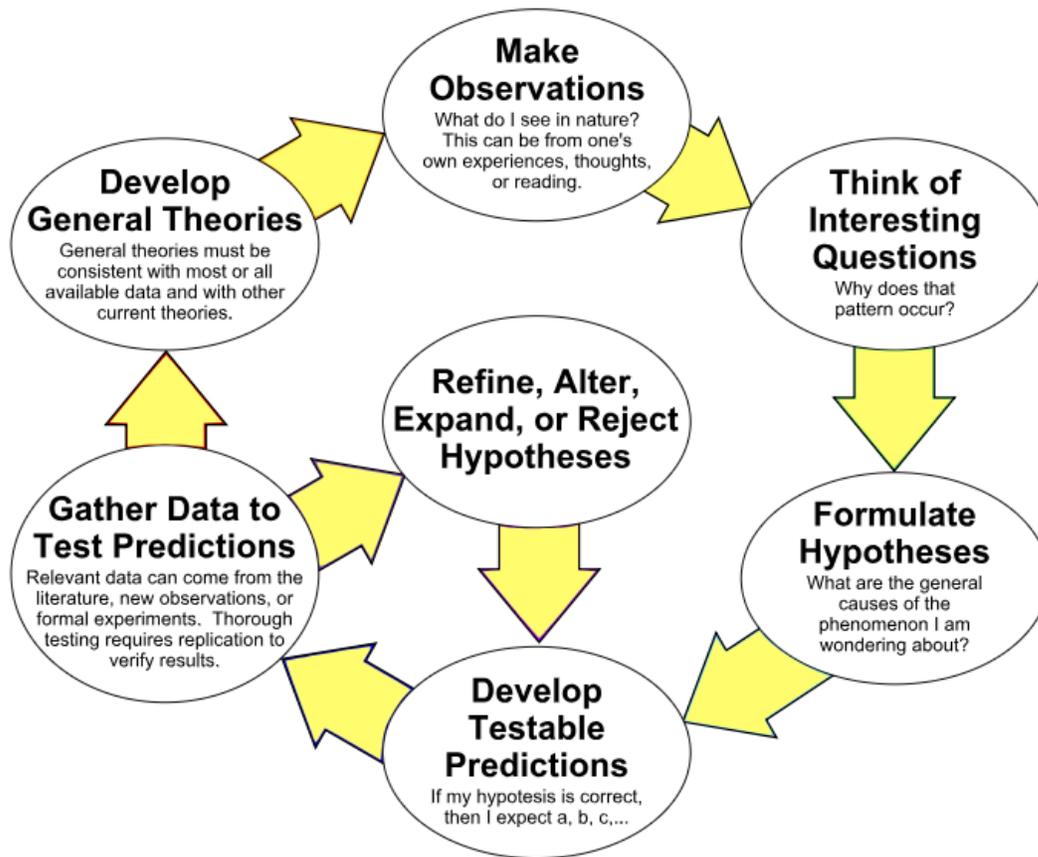
Photons and Sunburns

- Human skin contains carbon bonds.
- Why does UV light cause sunburns and not visible light?
 - UV radiation has higher energy photons because it has a higher frequency: $E = h\nu$
 - UV photons have enough energy to break apart carbon bonds, causing sunburns.
- Sunscreen works to either block or absorb UV rays.

THE END



The Scientific Method as an Ongoing Process



LAB REPORT TEMPLATE

Title:

- *A brief concise, yet descriptive title*

Statement of the Problem:

- *What question(s) are you trying to answer?*
- *Include any preliminary observations or background information about the subject*

Hypothesis

- *Write a possible solution for the problem*
- *Make sure this possible solution is a complete sentence*
- *Make sure the statement is testable*
- *The statement should reference the independent and dependent variables: such as “The plant group receiving (independent variable i.e. fertilizer) will (dependent variable i.e. produce more fruit) than the plants that did not receive (independent variable i.e. fertilizer)”*

Materials:

- *Make a list of all items used in the lab*

Procedure:

- *Write a paragraph or a list which explains what you did in the lab.*
- *Your procedure should be written so than anyone else could repeat the experiment.*

Results:

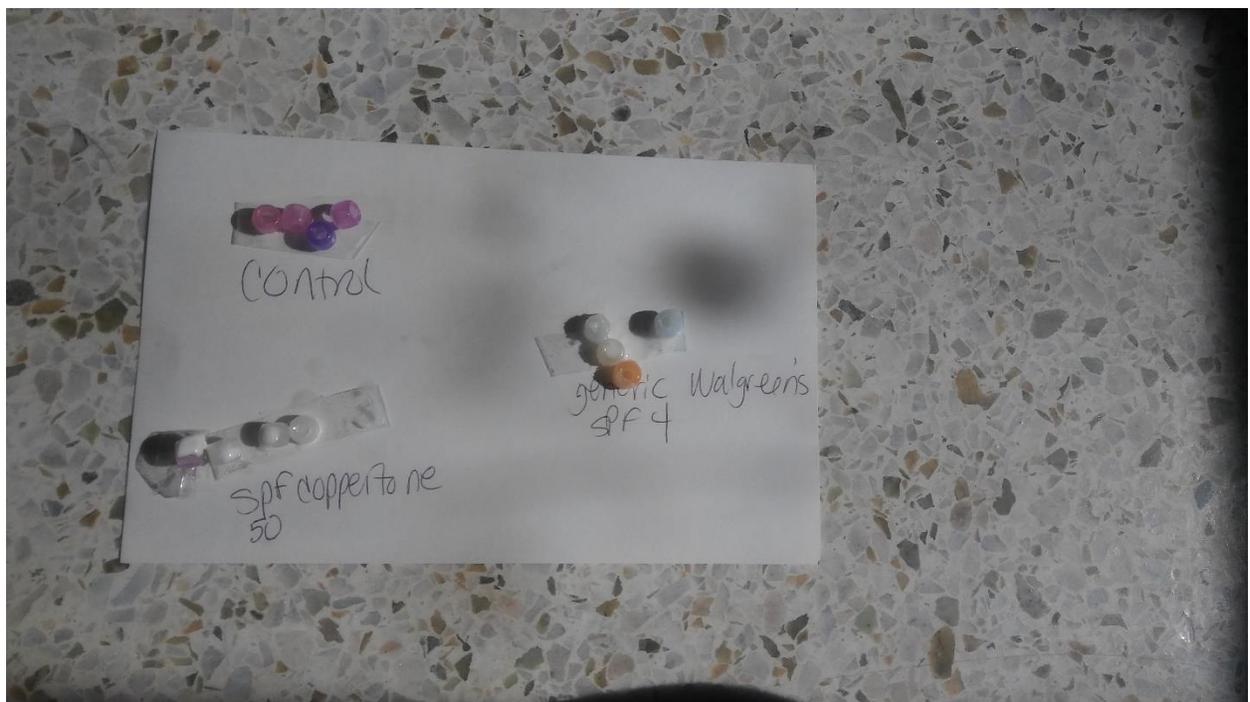
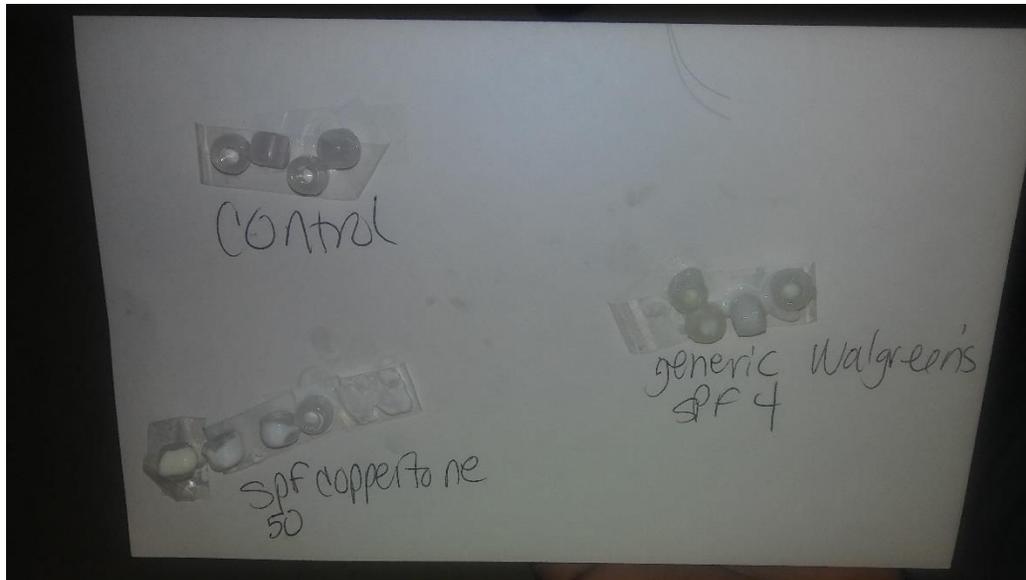
- *This section should include any data tables, observations, or additional notes you make during the lab.*
- *Although some students may wish to recopy original data: it is important to always preserve the original*
- *You may attach a separate sheet(s) if necessary.*
- *All tables, graphs and charts should be labeled appropriately.*

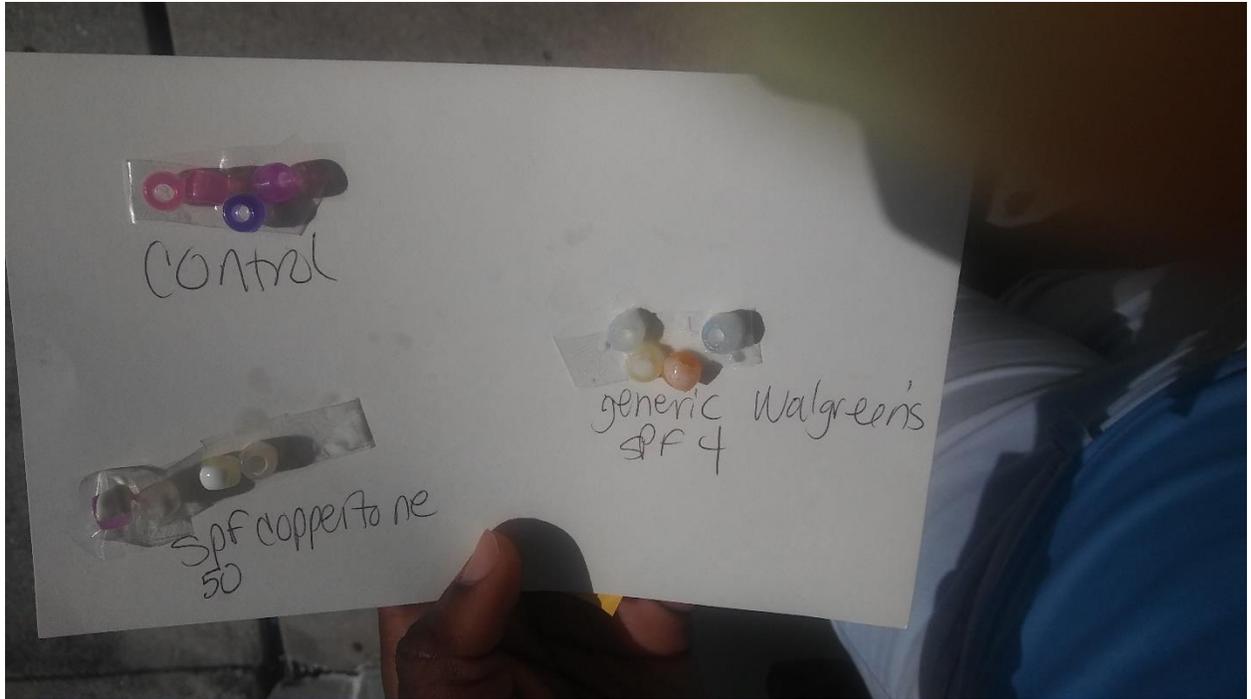
Conclusions:

- *This is what I learned/observed, this is possible sources of error, this is what could improve my research.*

Samples of UV beads in sunlight

Prior to sunlight





After 10 minutes in the sunlight