CSEO SCIENTIST IN THE CLASSROOM PARTNERSHIP

Ultraviolet Light

Fall 2022

Goal: To study the properties of ultraviolet light (UV light). To use a UV light source to study fluorescence. To test the ability of various substances to protect against UV light.

TN State Standards:

7.ESS3.2 Engage in a scientific argument through graphing and translating data regarding human activity and climate.

8.PS4.1: Develop and use models to represent the basic properties of waves including frequency, amplitude, wavelength, and speed.

PSCI.PS4.4 Describe and communicate the similarities and differences across the electromagnetic spectrum. Research methods and devices used to measure these characteristics.

Lesson Outline:

I. Introduction

A. Electromagnetic Radiation

Briefly explain electromagnetic radiation and point out the different types - X rays, UV, visible light, IR, and radio waves. Mention that the difference in energy is because of their differences in wavelength or frequency. They all travel at 300 million meters per second (speed of light).

B. What is Ultraviolet light?

Show students where UV light occurs in the electromagnetic spectrum. Explain that there are 3 kinds of UV light, depending on the wavelength (UVA, UVB, UVC).

II. Demonstrations

A. How Does A Blacklight Work?

Fluorescent and blacklight bulbs contain mercury vapor that emits UV light when its excited electrons return to the ground state. Blacklights have a special glass bulb that absorbs most of the visible light.

B. How Can UV light Be Detected?

Some chemicals absorb UV light and then re-emit the energy as light that we can see (visible light).

1. Bluing Agent Demonstration

Dip a Q-tip in the bottle of bluing agent and write something in large letters on a paper towel. When the black light is shown on the paper towel, the letters fluoresce.

2. Other materials treated with optical brighteners. Shine the black light on white paper and newspaper. The white paper will fluoresce, but the newspaper won't. Shine the black light on white T-shirts, white tennis shoes, etc. that students are wearing to see if any of the items fluoresce.

C. How Is UV Light Useful?

Discuss how UV lights can be used. Examples are to kill bacteria, attract bugs, detect forgeries, detect bodily fluids in forensic work.

D. How is UV light dangerous?

Ultraviolet light has more energy than visible light, and can damage living cells.

Discuss Ozone Depletion

III. Testing UV Blocking Materials.

Show the students the necklace made from UV beads and demonstrate the UV bead sensitivity to UV light by shining the black light on the necklace. Each group will use the purple UV-sensitive beads and a black light to test a variety of items. The items tested are:

1. a control bead, SPF 45 sunscreen, a sunglass lens, and a piece of T-shirt
2. a control bead and two types of milk containers (white and yellow).
3. a control bead, a piece of glass and a pill bottle.

IV. Review

Ask students to look at the observation sheets while you review the results with them.

V. Making a UV-sensitive bead bracelet

Students make a bracelet from UV-sensitive beads that they get to keep. The beads will detect UV radiation The UV-sensitive beads will continue to glow after the black light is removed.

Materials for Eight Groups

9 Black Lights
30 sheets of white paper towels
1 Bottle of Bluing (Clorox-2) for bluing demonstration
1 piece of copy paper (for demonstration)
1 piece of newspaper for demonstration
32 handouts - Electromagnetic Spectrum
16 Instruction Sheets
1 necklace made from UV-sensitive beads
9 #1 Ziploc bags containing:
- 4 UV-sensitive beads that turn purple in UV light (in mini bag)
- 1 lens from a pair of sunglasses
- 1 piece yellow milk carton
- 1 piece white milk carton
- 1 piece of T-shirt material
- 1 piece of glass
- 1 pill bottle
- 1 clear plastic plate marked with two lines

1 #2 Ziploc bags containing
- 1 1-oz wide-mouth bottle for SPF 45 sunscreen
- 1 paper towel
- 1 piece of acetate sheet
- 1 Q-tip

1 Ziploc bag marked for used acetate sheets, sunscreen coated UV beads and Q-tip
32 pieces of braid for stringing beads - each one is tied off on one end with one UV bead
32 1oz cups
1 jar beads (about 150, 5 per student)
42 safety goggles

I. Introduction

- Write the following vocabulary words on the board while the others are giving each student an Electromagnetic Spectrum handout:

electromagnetic radiation spectrum visible light ultraviolet light SPF ozone

A. What is the Electromagnetic spectrum (EM Spectrum)?

- The **electromagnetic spectrum** is the arrangement of all the different types of electromagnetic waves.
- Tell the students to look at the EM spectrum on the observation sheet.

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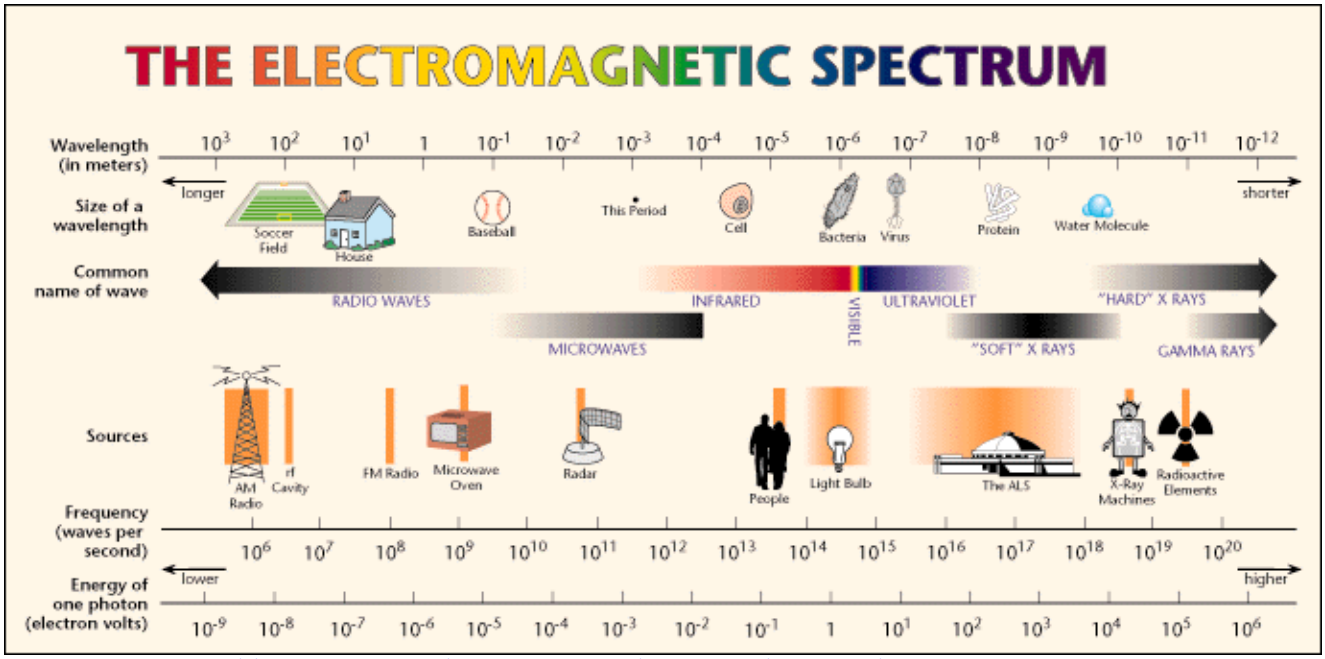
- Discuss briefly (**not more than 3 minutes**) the different parts of the electromagnetic spectrum.
- Point out that there are several different types of waves – radio, microwave, infrared, visible, ultraviolet, x-rays and gamma rays. These waves have different wavelengths, frequencies and energies.
- Point out the region in the electromagnetic spectrum where ultraviolet light occurs.
- Tell the students that today's lesson will be focusing on **ultraviolet light** (UV light).



Source: http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

- Tell students that the light we see is **visible light.** It appears to be white, but is made up of many colors.
- Visible light has wavelengths ranging from 400 to 700 nanometers (1nm = 1 X 10-9 m).
- These wavelengths are a small section of the full **electromagnetic** spectrum.

B. What is UV light?

- UV stands for Ultraviolet, a portion of the light spectrum that is beyond the violet light that we can see with our eyes.
- Humans cannot see UV light.
- Ask students to look at the visible light spectrum (below) and identify the colors that make up visible light. ROY G BV is a common acronym to remember the colors of white light (Red, Orange, Yellow, Green, Blue, Violet).

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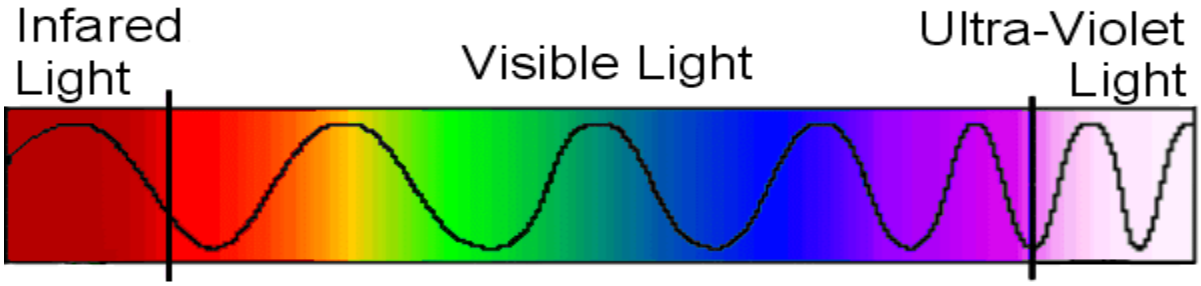


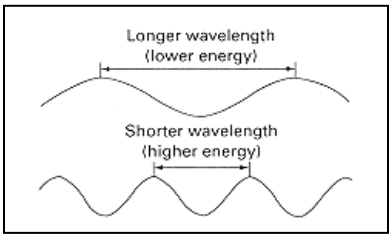
R O Y G B V

Long Wavelength
700 nm

Short wavelength
400 nm

Note: The I in ROYGBIV has been removed.

- Draw a wave on the board and show the students how a wavelength is measured.



- Point out that the wavelengths longer than the visible red are called **infrared** and the waves shorter than violet are called **ultraviolet**.
- UV waves have shorter wavelengths and higher energy than visible light.
- Ultraviolet light is produced by the sun. What happens when it reaches the earth's atmosphere? Most UV radiation is absorbed by the atmosphere or reflected back into space.
- Like visible light, Ultraviolet light has many different wavelengths. There are three categories of UV radiation: UVA, UVB, and UVC.
    - **UVA:** (at 400-315nm) is the closest to the visible light. It fades colors in plastics and clothes and contributes to smog. Black lights emit wavelengths around 365nm.
    - **UVB:** (315-290nm) is mostly absorbed by the ozone layer in the atmosphere, but the amount that makes it through can damage the DNA molecules in living cells and cause sunburn. The amount of UVB light that reaches the ground depends on where the sun is

Your Notes:

in the sky, the amount of ozone in the atmosphere, and the cloudiness of the sky. On a clear summer day, the maximum amount of UVB radiation occurs around midday, and so the most intense sunburn radiation occurs between the hours of 11am - 1pm.

- **UVC:** (290-220nm) is very dangerous, but it is all blocked by the earth's atmosphere (the ozone layer).

II. Activities and Demonstrations

- Show the students a small "black light" and turn it on. Explain that the purple glow is light from the visible, not the ultraviolet part of the EM spectrum.
- A **black light** emits UV radiation in the 300-400nm range plus some visible light.
  It works in the same way that fluorescent lights work. Both bulbs contain mercury vapor inside the bulb.
  When the bulb is electrified, electrons of the mercury atoms are excited and when they return to the ground state, UV light is emitted.
- In **fluorescent bulbs**, the UV light is absorbed by the white coating (the phosphor) and reemitted as white light.
- In **black lights,** a different phosphor is used to produce the UV light, as well as a special glass for the bulb which blocks almost all of the visible light.

A. Since we cannot see ultraviolet light, how can it be detected?

- Some chemicals absorb UV light and then re-emit the energy as visible light.
- The visible light disappears when the UV source is removed.
- The disappearance is either immediate (this is called fluorescence) or slow (this is called phosphorescence).

1. Bluing Agents - Demonstration

- Take a piece of paper towel and a Q-tip.
- Dip the Q-tip in the bluing agent and write something in big letters on the paper towel.
- Hold the black light over the paper towel. The letters will be fluorescent blue.

Explanation:

The bluing agent in the bottle is Clorox2, which lists as one of its ingredients an **optical brightener** – these chemicals absorb UV light and emit visible light through fluorescence. These brighteners are added to detergents to make washed clothes look whiter. When optical brighteners are incorporated into textiles, they make the material appear brighter and whiter, thus giving the appearance of being cleaner.

Note: Students see blue color immediately after the black light is shone, but the blue color is gone as soon as the black light is removed. Explain that this is **fluorescence.**

Your Notes:

2. Demonstration of other items that fluoresce.

- Hold the black light over a piece of copy paper to show that it fluoresces with a blue light.
- Hold the black light over a newspaper to show that it doesn't fluoresce, which shows that bluing agent isn't added to newsprint.
- Hold the black light over someone's tennis shoes or over a white T-shirt or article of white clothing.

B. How Can UV light be Useful?

- Ask the students if they know any uses for UV lights.
- Ultraviolet lights are used by forensic scientists to detect bodily fluids.
  - They can also be used to kill bacteria.
  - Bug Zappers use UV light to attract insects.
  - UV lamps are used to detect fake dollar bills ($5 and up).
- Tell students to look at their handout sheet.
- The bottom picture shows a copy of a $20 bill that has been exposed to UV light.
- Notice the **fluorescent strip.**

  This strip can be seen on the bill in visible light, but fluoresces only under UV light.

  Bills of different denominations have strips that fluoresce different colors and are at different positions on the bill.

  The $1 bill does not have a strip.

C. How is UV light dangerous?

- Ultraviolet light has more energy than visible light, and can damage living cells.
- When UVB light damages DNA, our cells might not work correctly. Sometimes this makes the cells grow uncontrollably, a condition called cancer.
- UVB light also damages the tissue in our eyes and can cause cataracts.

Your Notes:

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- We should block as much UV light from our bodies as is possible.
- How do you know if your skin has received too much UV light?
    - It turns red and becomes tender, i.e., you get a sunburn.
- What are some ways to block UV light?
    - There are many ways to block UV light. They include: sunscreen, long sleeves and pants, wide brimmed hats, sunglasses, and staying in the shade. Glass in windows transmits less than 10% of sun-burning UV light.

Discussion: Ozone Depletion

Ask the students if they know how the earth's atmosphere is protected from too much UV radiation.

- In the upper atmosphere, ozone is a "good" gas, since it screens out dangerous UV rays. But close to ground it is a pollutant and can act as a greenhouse gas.
- Ozone is an essentially colorless gas (pale blue at high concentrations) that has a distinctively sharp and unpleasant smell.
- Ozone is naturally formed in the atmosphere when UV rays react with O_2.
- The amount of screening of UV radiation from ozone has decreased by about 3% over the last decade.
- An ozone hole forms over Antarctica every spring (this has happened since the late 1970s. Ozone loss in the polar regions during the winter and spring can be as great as 50-70 % of what is normally present.
- Ozone losses over the Antarctica may contribute to changes in ozone over the whole globe. This decrease causes an increase in UV rays reaching the earth's surface.
- Ozone depletion is primarily caused by chlorine contained in chlorofluoro carbons (CFC's). The production of CFC's is now regulated, but it will be at least 50 years before the ozone level reverts to the level present before depletion began.
- Some countries announce a "time-to-burn" index.

From: www.atm.ch.cam.ac.uk/tour/index.html

III. Testing UV Blocking Using UV Sensitive Beads

- Divide the students into 8 groups and give each group one of the UV lights.
- Show the students a string of UV detecting beads. Point out that all the beads are white.
- Expose the necklace to a portable UV light, until the beads have turned color.
- Explain that this color change is due to the presence of UV light. The beads contain a chemical that absorbs the UV light and reemits it as visible light.
- Point out the purple beads in the necklace and tell the students that they will be using just the purple beads for this experiment because these change to a more intense color than the others.
- Notice that the color stays for some time after the necklace is no longer exposed to UV radiation. Since the color fades slowly, this is an example of **phosphorescence**. It eventually disappears.

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For instructor information only: The color change involves a dye molecule absorbing UV energy to produce a different geometric isomer of the molecule. When the UV energy is removed, the color slowly fades as the dye molecule rotates back to the more stable form.

What does sunscreen do?

- Since most students should be familiar with sunscreen and SPF, keep this discussion brief.
- Most students will probably answer that sunscreens keep you from getting sunburned.
- The one aspect they may not know is that the only light waves affected by sunscreen are those in the UV range. There are special chemicals in sunscreens that absorb the UV light, preventing it from reaching your skin.

How do you know how well a sunscreen blocks UV light?

- All sunscreen is labeled with an **SPF** (**S**un **P**rotection **F**actor) number that indicates how well it absorbs UV light.
- For example, an SPF of 15 means that it should take 15 times as long for skin damage to occur as it would on unprotected skin.
- Doctors recommend that everyone (even those with dark skin) wear a sunscreen with an SPF of at least 15 whenever they are in the sun.

Who should wear sunscreen?

- Everyone! "Although darkly pigmented persons develop skin cancer on sun-exposed sites at lower rates than lightly pigmented persons, UV exposure will still increase their risk for developing skin cancer."

Distribute the following to each group:

The Ziploc bags of materials to be tested
1 paper towel
1 blacklight
Distribute a pair of goggles to every student, and instructors. (The goggles will block any UV radiation from reaching eyes.)

A. Demonstrating the procedure:

- Tell the students they will be testing several items to see how well they block UV radiation. They will be using the UV-sensitive beads and observing their color change.
- Tell them they need to have a **control** bead to compare the effect of the protection. The control bead will be completely exposed to the UV light, whereas the other beads will have some protection.
- Show the students the clear plate marked with the 2 lines. Explain that all the materials to be tested need to be put between these 2 lines.

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- Show the students one of the acetate sheets and then place it on the clear plastic plate. Show them a Q-tip and the 1-oz container of SPF 45 sunscreen.
- Dip the Q-tip in the sunscreen, spread a good amount on the acetate, and immediately put a UV-sensitive bead on top of the sunscreen. (Tell them this is important to prevent the sunscreen from drying out.) **Emphasize that they should try to avoid getting any sunscreen on the plate, since it is difficult to wash off.**
- Put the lens of a sunglass and the piece of T-shirt on the plate within the 2 lines. Place a UV-sensitive bead on top of these. Tell the students they will be exposing these items to UV light and will be observing the color changes that occur.

- Place the plate directly on top of the black light so that the area in the middle of the plate is above the bulb.
- Leave the plate there for about two minutes (until the control bead has turned purple) and then take it off and place it on a piece of white paper towel.

B. Student Testing

1. Sunblock, sunglass lens, T-shirt
   - Tell the students they should follow the same procedure, using the SPF 45, sunglass lens, and piece of T-shirt.
   - After exposing the items to the black light, they should place the plate on the paper towel and make their observations as quickly as possible. Record them on the observation sheet.
   - Tell the students to carefully remove the acetate sheet and bead covered with sunscreen and place them on the paper towel with the Q-tip. Take care not to smear sunscreen on the plate. Remove the sunglass lens and piece of T-shirt and put them back into the Ziploc bag.
2. Milk Containers (white and yellow)
   - Repeat this procedure, using the control bead and two types of milk containers (white and yellow).
3. Glass, Pill Bottle, and Control
   - Repeat again by testing a piece of glass, pill bottle and control bead.

Ask students how they could test if the goggles prevent UV light from damaging their eyes.
By placing a UV detecting bead inside up-turned goggles and holding the goggles over the black light.
If there is time, have the students perform this test with the extra goggles.

Note: Ask the students to look at the observation sheets while you review the results with them.

IV. Review

- Does **sunscreen** really work? *Yes*
- Do **sunglasses** block UV? *Yes*

Your Notes:

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- You may want to elaborate that these sunglasses were cheap. The cheapest we could buy. Expensive glasses may provide no more UV protection than these.

- Does **clothing** protect you from UV light? *Yes*

- Which **milk jug** gives better protection? *yellow*
  Purity advertises that their milk is better because it came in a yellow plastic carton.
  Are they right? *Yes*

UV light damages many things other than human skin. One of the vitamins added to milk is vitamin D. If vitamin D is exposed to UV radiation, it will begin to break down and not be useful to the body anymore.

Vitamin C, also breaks down when exposed to UV light. Juices high in vitamin C, like orange juice, are packaged in **opaque containers**.
The white milk jug may offer slightly more protection than the glass.

- Are drugs protected in the **yellow bottles**? *Yes*.

- Typical **window glass** transmits some UVA but not UVB (this is why you don't get sunburned while driving in a car with the windows up).

Clean-Up and Return of the Kit:

1. Collect plates and put in a separate plastic bag (this is done to prevent sunscreen from contaminating the plates.
2. Students should place everything else (especially the acetate with bead covered with sunscreen – we wash and reuse these) back in their ziploc bag.
3. Instructors will collect and return everything to the CSEO.

Note: Be sure to collect all black lights. Count to make sure you have nine. Check that they are turned off and place them back in the kit box before you go on with the Review Sections.

V. Making a UV-Sensitive Bracelet

Note: If there isn't enough time, hand out the UV bracelet materials and tell them to make the bracelet at home. If this is done, take the assembled UV bracelet and repeat the demonstration with the black light.

Give each student a cup of 5 UV beads and 1 piece of braid.

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- Tell the students to string the beads onto the braid. After they have finished stringing the beads, they should make a bracelet by putting the untied end through the hole in the bead on the tied-off end and tying a knot.
- When they are finished, they should shine their black light on the beads. (The beads take a few minutes to develop the full color.) Notice that the beads continue to glow after the black light is removed.
- Tell the students they get to keep the bracelet and should use it to measure the amount of UV radiation on sunny days. They could keep a diary of their results – trying different times of the day and different times of the year – summer vs. winter.

Originally written by: Pat Tellinghuisen, Director of VSVS
Rachel Shevin, VSVS student volunteer
Dr. Mel Joesten, Emeritus Professor of Chemistry

Reference: "Putting UV-Sensitive Beads to the Test" by Terre Trupp, Journal of Chemical Education, Volume 78, Number 5, May 2001 p. 648a&b.
Note – The UV-sensitive beads can be obtained from Educational Innovations catalog (www.teachersource.com). Use the UV-PUR beads for this experiment.
Additional Resources Consulted: (accessed May-July 2002)
http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5104a1.htm

Your Notes:

Ultraviolet Light - Observation Sheet

NAME _____

Vocabulary words:

Electromagnetic spectrum **visible light** **ultraviolet light**
fluorescence **phosphorescence** **SPF** **ozone**

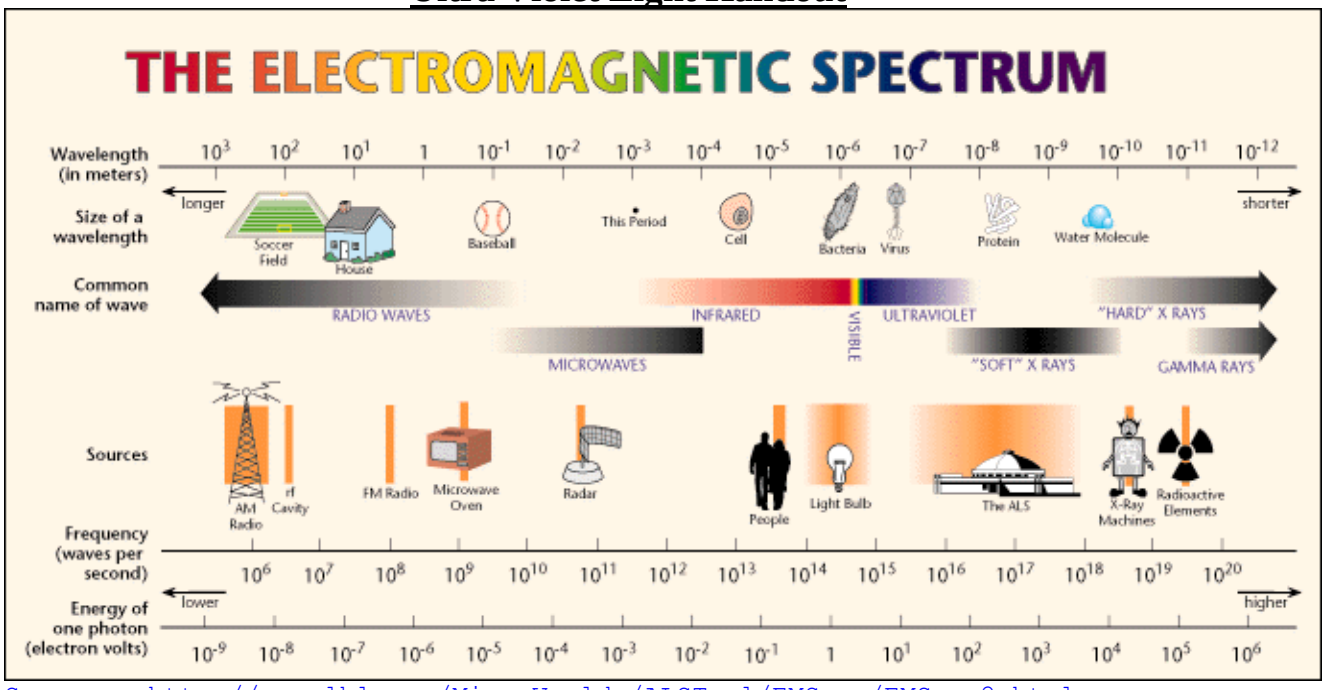
	No color change	Light purple	Purple
Experiment 1. Control UV Bead			
UV bead on SPF 45 sunscreen			
UV bead on sunglass lens			
UV bead on t-shirt			
Experiment 2. Control UV Bead			
UV bead on White milk carton			
UV bead on Yellow milk carton			
Experiment 3. Control UV Bead			
UV bead on Pill bottle			
UV bead on Glass			

Note: If there is no change in the original color of the bead, then the bead has absorbed no UV light. If the color of the bead has changed to a dark purple, then it has absorbed a lot of UV light.

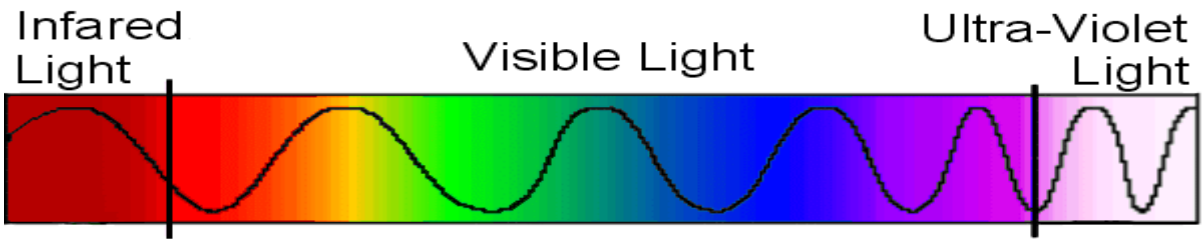
Review questions:

What **SPF** sunscreen should be worn when outside?
What kind of container would be best to store milk in?
Would it be better to store pills in a plastic amber pill bottle or in a regular glass bottle?
Does clothing protect your skin from UV light?

Ultra Violet Light Handout



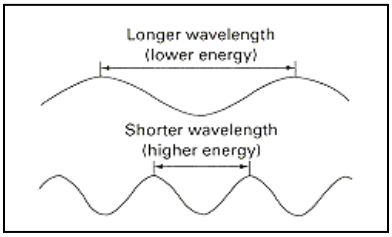
Source: http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html



R O Y G B V

Long Wavelength
700 nm

Short wavelength
400 nm
Blacklight 365nm



A $20 US bill exposed to UV light shows a blue strip with writing embedded in it. Other bills (the $1 does not have a strip) have strips in different places. At home, you can hold a bill up to a light and see the strip

INSTRUCTION SHEET
UV LIGHT

I. INTRODUCTION

A. Electromagnetic Spectrum

- Look at the electromagnetic spectrum on the handout and locate the different types of radiation.

B. What is Ultraviolet light?

- Find where UV light wavelengths occur in the EM spectrum.
- There are 3 categories of UV light – UVA, UVB, and UVC. They differ in wavelengths and energy. UVB and UVC are more dangerous than UVA.

II. ACTIVITIES AND DEMONSTRATIONS

A. How Does a Blacklight Work?

- Blacklights contain mercury vapor which releases energy as UV light. A phosphor converts this UV energy to a safer wavelength, and the blue glass absorbs most of the visible light.

B. How Can UV Light be Detected?

- Some chemicals absorb UV light and reemit it as colored visible light.
    1. **Bluing agent demonstration**
       Instructor demonstrates bluing agent using Clorox2.
    2. **A blacklight is shone on other articles to show the presence of optical brighteners.**
    3. **Narra Wood Water Extract Fluorescence Demonstration**

C. How is UV Light Helpful?

- Can be used to kill bacteria, to detect counterfeit bills, and by forensic specialists.

D. Why is UV Light Dangerous?

- UV light has more energy than visible light.
- Discuss the ozone hole.

III. TESTING UV BLOCKING MATERIALS

A. Demonstration

B. Activity

- Put on your goggles.
- Look at the clear plate and notice the 2 lines drawn on it. All materials to be tested should be placed within these lines.

Experiment 1.

- Use a Q-tip to spread SPF 45 on the acetate sheet and put a UV-sensitive bead on the SPF spot. Take the plastic plate and line up the following items on the center of the plate between the lines.
    1. A control UV-sensitive bead
    2. The acetate sheet with its UV-sensitive bead
    3. The lens of a sunglass
    4. The piece of T-shirt
- Then place a UV-sensitive bead on top of the lens and T-shirt.
- Turn the black light on and place it on the desk or table in front of the group.
- Place the plate directly on top of the black light so that the lines are parallel with the tube.
- Leave the plate exposed to the black light for about 2 minutes.
- Remove the plate, and place it on the paper towel. How has the color of the beads changed?
- Record your observations on the observation sheet.
- Clean-up: remove the acetate square with the bead and place it on the paper towel. Keep the other beads for the next experiment. Put the lens and T-shirt back in the plastic bag.

Experiment 2.

- Repeat this procedure, using the control bead and two types of milk containers (white and yellow) with UV-sensitive beads on top of them.
- Record your observations.

Experiment 3.

- Repeat the procedure again, using the control bead and UV-sensitive beads on top of a piece of glass and a pill bottle.
- Record your observations.

IV. REVIEW

V. MAKING A UV-SENSITIVE BEAD BRACELET

- A instructor will give you some beads and a piece of braid.
- String the beads onto the braid. After you have finished stringing the beads, make a bracelet by putting the untied end through the hole in the bead on the tied-off end, and tie a knot.
- Shine the black light on the beads for 2 minutes and then remove the light.
- Observe the colors in your UV-sensitive bracelet. Notice that the beads continue to glow for a few minutes after the black light has been removed. This is phosphorescence.
- Take the UV bracelet home. Try using it to measure the amount of UV light by wearing it outside on sunny days to see if the UV beads develop color.