Penn State RET in Interdisciplinary Materials

You Do the Math – Calculating the Effects of UV Light

Purpose:

This lab is designed to help students understand and practice many different types of mathematical concepts that can be explored as part of the study of UV light.

Objectives:

Students will

- Describe wavelengths and the major regions of the electromagnetic light spectrum.
- Mathematically describe the effect of negative exponents
- Define and describe nanoscience
- Describe SPF and what factors contribute to the protective rating.
- Describe the method for determining the UVA
- Use EXCEL to graph the results of an experiment

Time required:

Three class periods.

Level:

Middle school

National Science Education Standards:

8ASI2.2 Current scientific knowledge and understanding guide scientific investigations. Different methods, core theories, and standards to advance scientific knowledge and understanding.

8ASI2.3 Mathematics is important in all aspects of scientific inquiry.

8ASI2.4 Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

8BPS3.6 The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of

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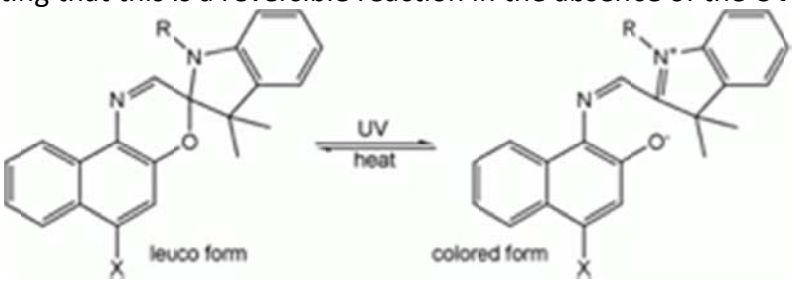
visible light, infrared, and ultraviolet radiation.

8EST1.4 Evaluate completed technological designs or products. Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors; they should also suggest improvements and, for their own products, try proposed modifications.

8EST1.5 Communicate the process of technological design. Students should review and describe any completed piece of work and identify the stages of problem identification, solution design, implementation and evaluation.

Teacher Background

UV sensitive beads are typically constructed of two large planar conjugated molecules. Before exposure to UV light, these molecules are not bonded and appear colorless. Upon exposure to the UV light, the two molecules bond to form a larger complex that absorbs certain wavelength of light, resulting in a visible color. The longer the conjugated molecule, the longer the wavelength of light absorbed and thus different colors of beads can be produced by using different molecules in production of the beads. When placed in the dark, the beads return to their colorless appearance, indicating that this is a reversible reaction in the absence of the UV light.



Chemical, biomedical and environmental engineering researchers are involved in addressing the problems that can result from too much UV radiation on human skin by studying the breakdown of the Earth's protective ozone layer and working to develop detection procedures and skin cancer treatments and cures. Understanding how these beads work as indicators can help engineers design better detection systems to help prevent skin cancer caused by UV radiation.

From: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p088.shtml#background

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Materials

- UV Beads
- 4 Styrofoam cups
- Water
- Ice
- Measuring cup
- Thermometers
- Meter Sticks
- Microwave oven
- Latex Gloves
- Goggles
- EXCEL
- Scientific Calculators
- Portable UV checker
- Handouts

Advance Preparation:

The teacher should order the UV beads and the UV checkers ahead of time.
Sources include: Steve Spangler Science
250 beads Item #: WUVB-250
UV Checker Item # Item #: WUVC-250

Safety Information:

Students should wear goggles and gloves when completing this lab.

Teaching Strategies:

Day 1-2 Activities may be completed either individually or in small groups within the class.
Day 3 Experiment should be completed in small groups of about 4 students each.

Resources:

Video-(NASA - Tour of the Electromagnetic Spectrum,
http://missionscience.nasa.gov/ems/emsVideo_01intro.html

Image of electromagnetic spectrum
http://gosperk.wikispaces.com/Electromagnetic+Spectrum+%26+Light

Image of UVA, UVB and skin
http://www.skincancer.org/prevention/uva-and-uvb/understanding-uva-and-uvb

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Calculating UV Index
http://www2.epa.gov/sunwise/calculating-uv-index

Image of Nanoparticles of Zinc Oxide
From: Julia Hsu, Neil Simmons and Tom Sounart, Sandia National Laboratory

Nanometer Scale
http://www.chemteam.info/Metric/Metric-Prefixes.html

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Procedure

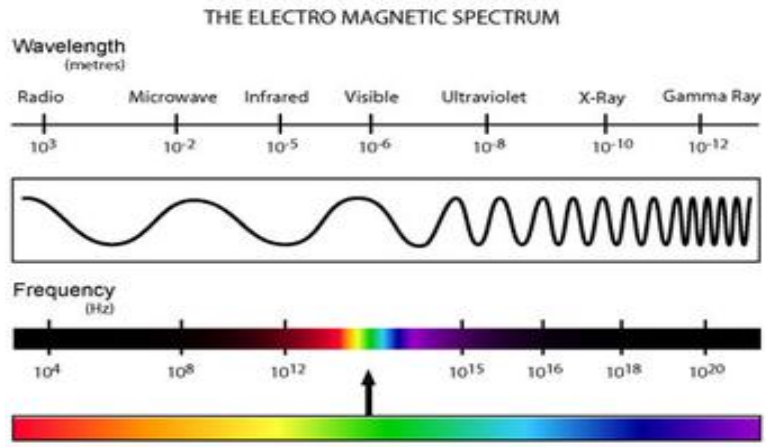
Day 1

The teacher should begin the lesson by discussing with the students the fact that the sun's rays are a form of electromagnetic radiation. Ask students what that means and list answers on board. Next, show an online movie about electromagnetic energy:

(NASA - Tour of the Electromagnetic Spectrum, http://missionscience.nasa.gov/ems/emsVideo_01intro.html)

Discuss with students the properties and uses of the different parts of the electromagnetic spectrum. Be sure to include information on gamma rays, x-rays, ultra violet light, visible light, infrared light and radio waves.

Allow students to break in small groups and explore the following handout.



http://gosperk.wikispaces.com/Electromagnetic+Spectrum+%26+Light

From:
http://gosperk.wikispaces.com/Electromagnetic+Spectrum+%26+Light

Explain to students that this lesson focuses on ultra violet light.
Have students research the difference between UVA, UVB and UVC light. Students should answer that each of these three types of light have different frequencies (UVC -100 -280 nm, UVB - 280-315 nm, and UVC – 315-400 nm) and thus different energies.

Questions to prompt discussion:

Why might we be concerned about UV light?
Are there any benefits to UV light?
What is the difference between UVA, UVB and UVC light?

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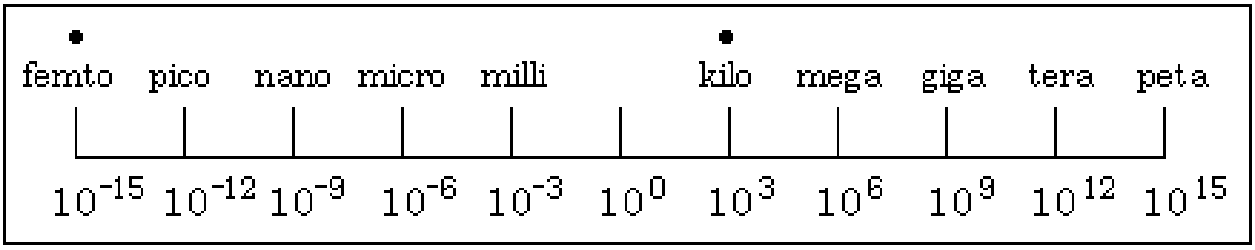
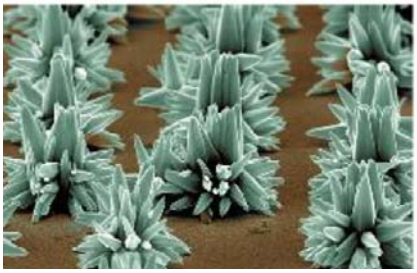
How do the sun's rays have the potential to harm us?
What does the "nm" mean?

Allow time for students to brainstorm and then return to contribute their answers.

Introduce the concept of nanometers.



From: http://www.chemteam.info/Metric/Metric-Prefixes.html



Magnified image of zinc oxide nanoparticles
From: Julia Hsu, Neil Simmons and Tom Sounart, Sandia National Laboratory

Imagine if you could fit 10 million points between 0 and 1 on a number line. The space between two of those points is a nanometer.
Lead a class discussion on this concept.

Useful Unit Conversions
1 meter (m) = 1 x 10^9 nanometers (nm)
1 meter (m) = 100 centimeters (cm)
1 inch (in) = 2.54 centimeters (cm)
1 foot (ft) = 12 inches (in)
1 meter (m) = 3.28 feet (ft)

Nano = 10^{-9}

Discuss how negative exponents change a number. Provide meter sticks and calculators for students to measure items in the classroom and then convert these measurements into nanometers. Work can be recorded in

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lab notebook.
Practice doing equations with negative exponents.

Wrap up today's lesson by asking for a review of what was discussed.

Day 2

Review with students the concepts that were previously discussed.

Questions to prompt discussion:
Do students wear sunscreen and why?
Which commercial products they use and what benefits do they offer?
What ingredients make up sunscreen?
Are there any nanoparticles in sunscreen?

Ask students to fold a piece of paper into thirds. Label each third in the following way:

Why Use Sunscreen?	What are the effects of too much sun exposure?	What ingredients are in sunscreen?

Students may need to research to complete this worksheet.
Gather together as a class and discuss the students' research and answers.

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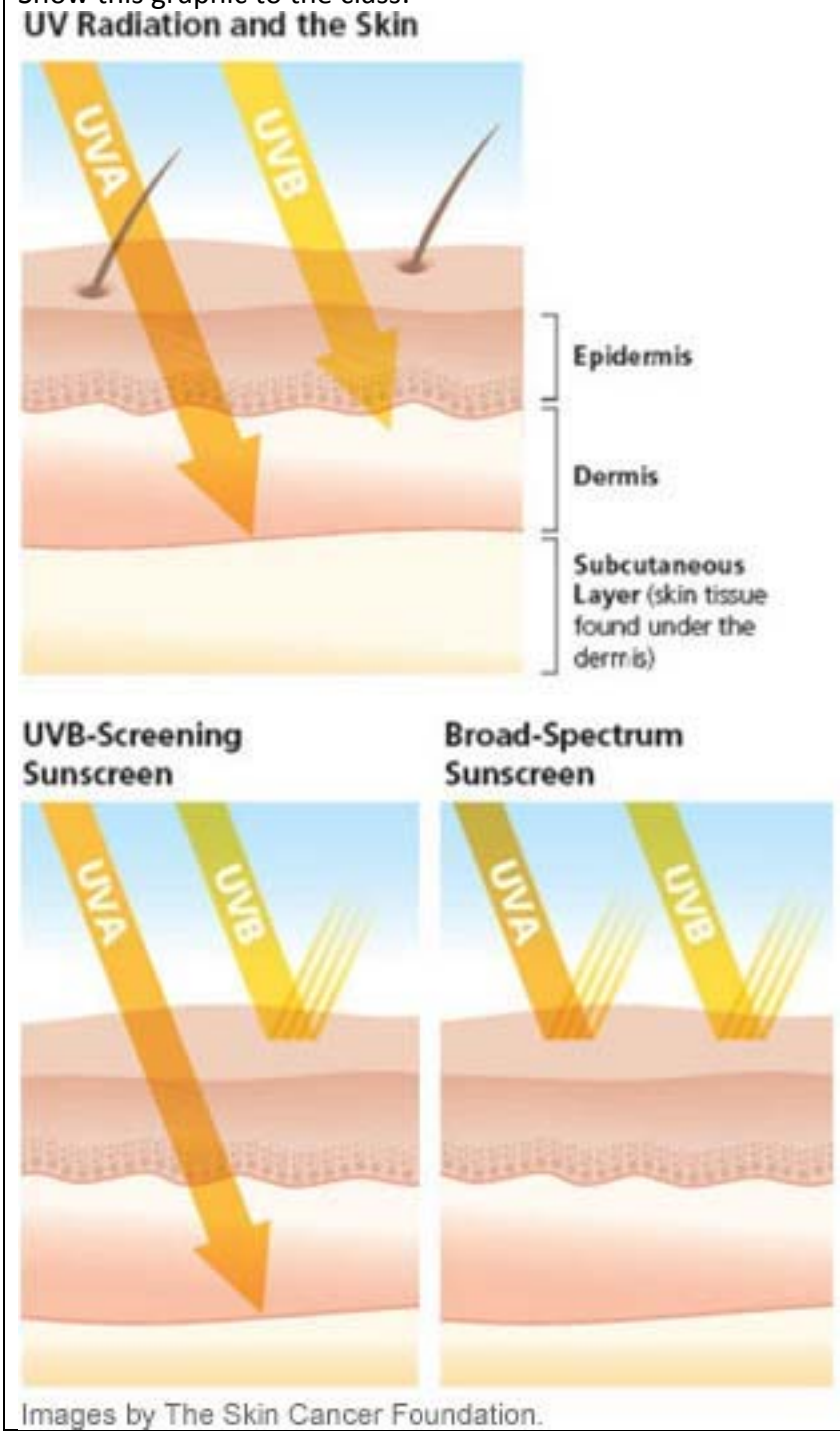
Show this graphic to the class:



Images by The Skin Cancer Foundation.

Discuss the sun's rays in terms of radiation. Radiation energy is determined by the frequency of the radiation times Planck's constant (6.26 x 10 -34 J s) Radiation is a type of energy and is measured in packets.

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The US government calculates the UV index daily. Provide this handout for students.

Calculating the UV Index

The U.S. National Weather Service calculates the UV Index using a computer model that relates the ground-level strength of solar ultraviolet (UV) radiation to forecasted stratospheric ozone concentration, forecasted cloud amounts, and elevation of the ground.

The calculation done by some other nations also includes ground observations. The calculation starts with measurements of current total ozone amounts over the entire globe, obtained via two satellites operated by the National Oceanic and Atmospheric Administration. These data are used to produce a forecast of stratospheric ozone levels for the next day at many points across the country. A computer model uses the ozone forecast and the incident angle of sunlight at each point to calculate the strength of UV radiation at ground level. Sunlight angle is determined by latitude, day of year, and time of day (solar noon). The strength of UV radiation is calculated for several wavelengths between 280 and 400 nm, the full spectrum of UVB (280-314 nm) and UVA (315-400 nm) radiation.

Ozone in the atmosphere absorbs (attenuates) shorter UV wavelengths more strongly than longer wavelengths. The strength of ground-level UV radiation differs significantly across the UV spectrum. As an example, UV strengths for a point might be calculated as shown in the table below. (These are hypothetical values. A National Weather Service chart shows typical UV irradiance values.)

Wavelength	Strength
290nm	4
320nm	26
400nm	30

The next step in the calculation adjusts for the sensitivity of human skin to UV radiation. Shorter UV wavelengths cause more skin damage than longer UV wavelengths of the same intensity. To account for this response, calculated UV strength

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is weighted (adjusted) at each wavelength using a function called the McKinlay-Diffey erythema action spectrum.

Continuing with our example, the table below gives skin response weighting factors for the UV wavelengths. (These are hypothetical values for the example, not actual McKinlay-Diffey weighting factors.) We multiply the ground-level UV strength by the weighting factor to calculate the result, the effective strength of the UV radiation, at each wavelength.

Wavelength	Strength	Weight	Result
290nm	4	15	60
320nm	26	5	130
400nm	30	3	90

Next, the effective UV strength at each wavelength across the 290 to 400 nm spectrum is summed (integrated), giving a value that represents the total effect of UV radiation on skin. In our example, the total UV effect is 280 (60 + 130 + 90).

The next step of the calculation adjusts for the effects of elevation and clouds. UV intensity increases about 6% per kilometer elevation above sea level. Clouds absorb UV radiation, reducing ground-level UV intensity. Clear skies allow virtually 100% of UV to pass through, scattered clouds transmit 89%, broken clouds transmit 73%, and overcast skies transmit 31%.

For our example, let us assume that the elevation is 1 kilometer and there are broken clouds overhead. The total UV effect, adjusted 6% for elevation and 73% for clouds, would be calculated as:

280 x 1.06 x 0.73 = 216.7

The final step of the calculation scales the total UV effect, dividing it by 25 and rounding to the nearest whole number. The result is a number that usually ranges from 0 (darkness or very weak sunlight) to the mid-teens (very strong sunlight). This value is the UV Index.

For our example, the UV Index would be:

216.7 / 25 = 8.7, rounded to 9

From: http://www2.epa.gov/sunwise/calculating-uv-index

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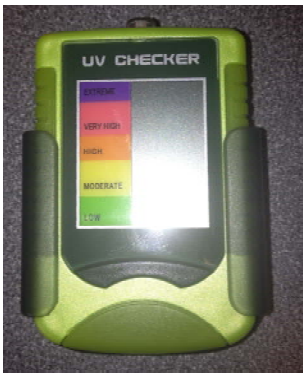
Follow the example on the handout.

Prepare cards with different values. For example: Elevation = 50 feet above sea level or cloud cover = 40%
Based on this change, have students go back to the handout and recalculate the UV. Students may work independently or in groups.

Questions to prompt discussion:

Why is it important to be aware of the UV index each day?
If it is a cloudy day, do you still need to wear sunscreen?
Can UV light travel through clothing?
What type of clothing would be the best/worse to wear on a sunny day?

Give each student some UV beads. Take the class outside to "test" the beads.
Use portable UV detectors.



Questions to prompt discussion:

What happens to the beads when they are exposed to sunlight?
How quickly does the reaction take place?
Is there any way to slow down this process?
How long does it take the beads to return back to their original color?
What experiments could you design that use these beads?

Wrap up today's lesson by asking for a review of what was discussed.

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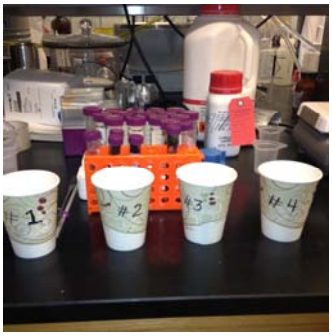
UV Beads and Temperature



Introduction

UV Beads contain different pigments that change color when exposed to ultraviolet light from any source, including the sun. The beads are all white in visible light. In UV light, depending on the pigment added to each bead, you will see different colors. Each bead will change color about 50,000 times before the pigment will no longer respond.

Materials

- UV beads
- goggles
- gloves
- scientific calculator
- Styrofoam cups
- Water
- Measuring cup
- Thermometer
- Stopwatch
- Microwave
- Ice
- Sharpies

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Make a Prediction

The cup that contains the ice water will be the last one to have beads change back to their original color.

Procedure

1. Wear goggles and gloves and be sure to have all materials ready at your work station.
2. Mark the cups #1, #2, #3
3. In cup #1, place 10 UV beads and add 250 ml of hot water, 60^0C (heat in microwave)
4. In cup #2, place 10 UV beads and add 250 ml of ice water, 0^0C
5. In cup #3, place 10 UV beads and add 250 of water at room temp, 20^0C (This is the control)
6. Cover the cups (to prevent exposure to sunlight) and carefully carry them outside.
7. Uncover and expose the cups to sunlight for two minutes. (Use stopwatch)
8. Cover and carry the cups inside.
9. Observe and use stopwatch to record how long it takes each of the cups of beads to return to their original color.
10. Record your results. Students should record the temperature in both Celsius and Fahrenheit.

Converting Fahrenheit to Celsius:	Converting Celsius to Fahrenheit:
((°F-32)x(5/9))=°C	(°C x (9/5))+32=°F

11. Clean up.
12 Use EXCEL to graph your results. Label the x and y axis and include a title and your name.

Record Your Observations

	Beginning Temperature		**Seconds**	**Ending Temperature**	
	C	F		C	F
Cup 1					
Cup 2					
Cup 3					

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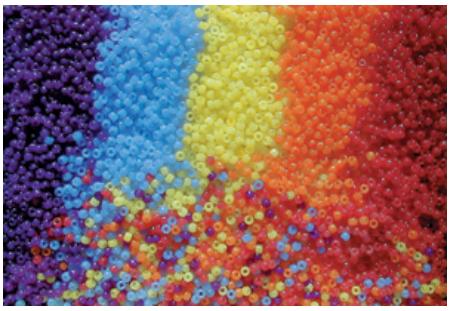
Analyze the Results

Use EXCEL to create a graph that shows your results. The x axis should be the temperature and the y axis should show the time in seconds.



Draw Conclusions

1. What conclusion can you make from the data collected?
   The colder the water the longer it will take for the beads to return back to their original color.

UV light is needed to excite the molecule to form the high-energy planar structure, but also heat from the surroundings provides the activation energy to change the molecule back to its colorless structure.

Assessment and rubrics:

Each student will complete the worksheet accurately. The temperature will be recorded in both Fahrenheit and Celsius.

Each student will complete a graph that includes temperature and time. The x and y axis will be labeled and the graph will include a title and the student's name.

Extensions:

Ask students to research "real world" applications for this technology.

Possible answer:

Smart windows or window films or glazes that adapt to sunlight and temperature are a potential use. This could add to the energy efficiency of windows while also limiting the damaging rays of the sun and heat.

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