Lesson 4:
How Sunscreens Appear: Interactions with Visible Light

Student Materials

Contents

Scattering of Light by Suspended Clusters: Student Reading

Figure 1a: Dust clusters from a passing car scatter sunlight

Figure 1b: Without the dust clusters we can not see the sun rays

What is Scattering?

Scattering is a phenomenon in which light is redirected in different directions by small clusters of atoms suspended in some other substance. A common example of scattering is when you shake out a dusty object in a sunny room - the dust seems to sparkle in the air. This effect occurs because the dust is scattering the sunlight, which then reaches your eyes. Scattering also explains why snow and salt are white, and why the sky is blue. In each of these situations, the light is being redirected many times before it reaches our eyes. This is why the process is called multiple scattering.

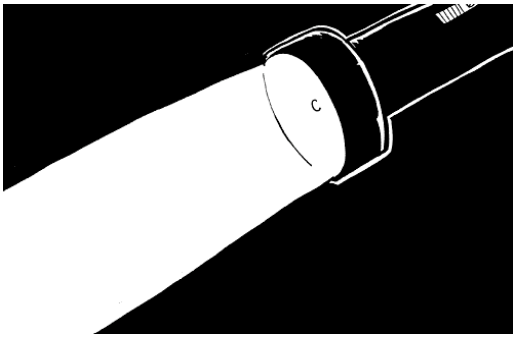

Figure 2: What is wrong with this picture?[1]

In many cartoons we often see the “light” from a flashlight in the dark, but this is a false image because we can not see this light unless there are clusters there to scatter it towards our eyes. Try shining a flashlight at a wall in a dark room. Can you see the beam of light between the wall and the flashlight (like in the picture above)? Now sprinkle some baby powder in the air while you shine the beam. Can you see the beam now?

How Does Scattering Occur?

When lots of clusters of one material are suspended in another material (for example drops of water in the air, or active sunscreen ingredients in the lotion) light has a chance to interact with these many clusters. The interaction bends the light in many different directions. After this, it will then continue traveling in the suspension medium until it reaches another cluster. If the light is bent multiple times in multiple directions, we call this multiple scattering.

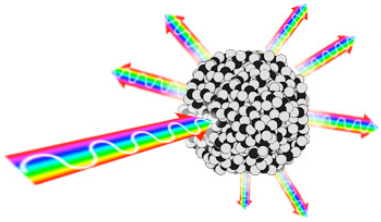

Figure 3: Scattering of light by a suspended cluster

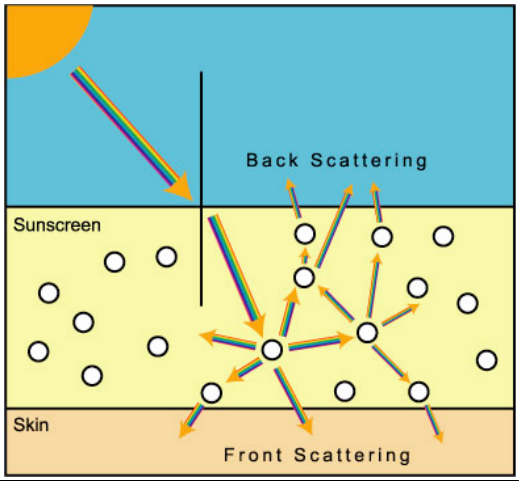

Figure 4: Multiple scattering of light by suspended cluster

While on the micro-level scattering redirects the light in many different directions, on the macro-level this combines to produce one of two results: the light is sent back in the general direction from which it came at various angles (back scattering) or the light continues in the same general direction it was moving, but at various angles (front scattering).

Does Scattering Always Happen?

Whether or not scattering will occur depends on many factors. For clusters suspended in a medium some of the most important factors are: the identity of the clusters, the identity of the suspending medium and the cluster size. Scattering happens most when the clusters have a diameter that is half as big as the wavelength of light involved. So a 200 nm cluster would scatter 400 nm light the most and it would scatter 300-500 nm light quite a bit as well. The amount of scattering continues to decrease as wavelengths become much bigger or much smaller than 400 nm, as shown in figure 5.

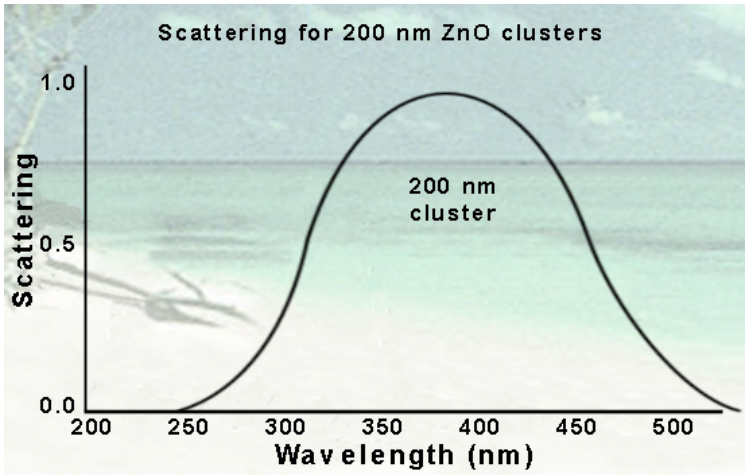

Figure 5: Graph of Scattering for a 200 nm ZnO Cluster in Sunscreen

References

(Accessed December 2005)

[1] http://www.liberty-news.com/showCartoons.php?artist=Lalo+Alcaraz&src=h2856

Ad Campaign Project: Student Instructions

Overview

Sunsol, the prominent sunscreen maker, has just decided to launch a new product into the market. The sunscreen will use a zinc oxide (ZnO) nanopowder as its only active ingredient, and will be formulated to go on clear and non-greasy. Sunsol is very excited about its new product, and wants to launch a full ad campaign to promote it to consumers who may not be familiar with the idea of a clear sunscreen that offers full spectrum protection.

Sunsol feels that it is very important for their potential customers to understand both how ZnO interacts with light to protect people's skin and how the size of the particles affects the sunscreen's appearance. For this reason, they have decided that the ad campaign should center on an animated commercial that shows how traditional ZnO and ZnO nanopowders interact with UV and visible light.

Sunsol has invited several creative teams—including yours—to use the ChemSense Animator to create animations showing how the different sized ZnO particles suspended in the sunscreen will scatter visible light differently.

The Request

Sunsol is requesting a total of 4 animations:

1. Sunscreen with ~50 nm ZnO particles interacting with UV light.
2. Sunscreen with ~50 nm ZnO particles interacting with visible light.
3. Sunscreen with ~300 nm ZnO particles interacting with UV light.
4. Sunscreen with ~300 nm ZnO particles interacting with visible light.

Your teacher will put you in teams and let you know which of the animations you should work on.

Animation Matrix

	UV light	Visible Light
50 nm ZnO particles	1	2
300 nm ZnO particles	3	4

Requirements

All animations should contain the following elements:

- A light source (the sun)
- A skin surface with sunscreen lotion applied
- ZnO particles of the required size suspended in the lotion
- A minimum of 10 frames

The UV light animations should also include:

- At least 2 UVA and 2 UVB light rays interacting with the ZnO particles (and skin when appropriate)
- All relevant blocking mechanisms for the ZnO particles in the sunscreen

The visible light animations should also include:

- At least 5 visible light rays interacting with the ZnO particles (and skin when appropriate)
- A human observer and an indication of what the they see

Things to consider in your animation

- How thick will the sunscreen be applied?
- What concentration of particles will the sunscreen have?
- How will you show the different blocking mechanisms?
- How will you indicate what the human observer sees?

Evaluation

Sunsol will evaluate the animations based on the following criteria:

- All required elements are present and accurately depicted
- Animations show correct interaction of light rays with ZnO particles (and skin)
- All relevant blocking mechanisms shown (UV light only)
- Animations clearly indicate what the observer sees and why (Visible light only)
- All team member contributed and worked together to produce the animations

Discussion

Questions to answer about each model:

- How does this model show absorption / scattering?
- How does this model show what the observer sees?
- What are its strengths? (What aspects of scattering does it show particularly well?)
- What are its limitations? (What aspects of scattering are not shown well?)
- Is there anything that seems inaccurately depicted?
- What could be done (within the structure of the animation) to address some of these limitations?

Questions to answer about the group of models as a whole:

- What do the different animations have in common? How do they show things in similar ways?
- What things do the animations show in different ways? Are different animations better at showing different aspects of the phenomenon?
- If different models can be used to represent a phenomenon, how do we know which one is “better”? (Models which best align with or represent the empirical data we have are better.)

Rubric for Ad Campaign Evaluation – UV Light Animations

Category	Novice (1) Absent, missing or confused	Apprentice (2) Partially developed	Skilled (3) Adequately developed	Masterful (4) Fully developed
Required Elements • Light source • Skin surface • Sunscreen lotion • Suspended ZnO particles • 2 + UVA rays • 2 + UVB rays • 10 + frames	0 - 2 of the required elements are present.	3 - 4 of the required elements are present.	5 – 6 of the required elements are present.	All 7 required elements are present.
	Few of the required elements are accurately depicted.	Some of the required elements are accurately depicted.	Most of the required elements are accurately depicted.	All of the required elements are accurately depicted.
Interactions of light rays with ZnO particles (and skin where appropriate) correctly shown	Few or no key aspects of the interaction are correctly shown.	Some aspects of the interaction are correctly shown.	Most key aspects of the interaction are correctly shown.	All key aspects of the interaction are correctly shown.
All relevant blocking mechanisms correctly shown	Few or no key aspects of the blocking mechanism are correctly shown.	Some key aspects of the blocking mechanism are correctly shown.	Most key aspects of the blocking mechanism are correctly shown.	All key aspects of the blocking mechanism are correctly shown.
Teamwork • All team members contributed significantly to the project • Group worked together to manage problems as a team	Few team members contributed to the project.	Some team members contributed to the project.	Most team members contributed to the project.	All team members contributed to the project.
	Group did not address the problems encountered.	Group did not manage problems effectively.	Problems in the group managed by one or two individuals.	Group worked together to solve problems.

Rubric for Ad Campaign Evaluation – Visible Light Animations

Category	Novice (1) Absent, missing or confused	Apprentice (2) Partially developed	Skilled (3) Adequately developed	Masterful (4) Fully developed
Required Elements • Light source • Human observer • Skin surface • Sunscreen lotion • Suspended ZnO particles • 5 + visible light rays • 10 + frames	0 - 2 of the required elements are present.	3 - 4 of the required elements are present.	5 – 6 of the required elements are present.	All 7 required elements are present.
	Few of the required elements are accurately depicted.	Some of the required elements are accurately depicted.	Most of the required elements are accurately depicted.	All of the required elements are accurately depicted.
Interactions of light rays with ZnO particles (and skin when appropriate) correctly shown	Few or no key aspects of the interaction are correctly shown.	Some aspects of the interaction are correctly shown.	Most key aspects of the interaction are correctly shown.	All key aspects of the interaction are correctly shown.
What the observer sees and why they see is correctly shown	Few or no key aspects of the observer's view are correctly shown.	Some key aspects of the observer's view are correctly shown.	Most key aspects of the observer's view are correctly shown.	All key aspects of the observer's view are correctly shown.
Teamwork • All team members contributed significantly to the project • Group worked together to manage problems as a team	Few team members contributed to the project.	Some team members contributed to the project.	Most team members contributed to the project.	All team members contributed to the project.
	Group did not address the problems encountered.	Group did not manage problems effectively.	Problems in the group managed by one or two individuals.	Group worked together to solve problems.

Name_____ Date_____ Period _____

Sunscreens & Sunlight Animations: Student Instructions & Worksheet

Introduction

There are many factors that people take into account when choosing which sunscreen to use and how much to apply. Two of the most important factors that people consider ate the ability to block UV and the visual appearance of the sunscreen (due to the interaction with *visible* light). You are about to see three animations that are models of what happens when sunlight (both UV and visible rays) shine on:

- Skin without any sunscreen
- Skin protected by 200 nm ZnO particle sunscreen
- Skin protected by 30 nm ZnO particle sunscreen

Open the animation file as instructed by your teacher and explore the animations for different sunscreen and light ray options. Then choose the sunscreen option and wavelength(s) of light as indicated to answer the following questions.

Questions

1. Select the UVA and UVB wavelengths of light with no sunscreen and click the play button.
   a. What happens to the skin when the UV light reaches it?

   b. How is the damage caused by the UVA rays different from the damage caused by the UVB rays? (You may want to play the animation with just UVA or UVB selected to answer this question)

   c. Based on what you know about the different energies of UVA and UVB light why do you think this might happen?

2. Now leave UVA and UVB light selected and try playing the animation first with the 30 nm ZnO sunscreen and then with the 200 nm ZnO sunscreen.
   a. What kind of sunscreen ingredients are shown in each animations?

   b. What happens to the UV light in the animation of 30 nm ZnO particle sunscreen?

   c. What happens to the UV light in the animation of 200 nm ZnO particle sunscreen?

   d. Is there any difference in how the UV light interacts with the 30 nm ZnO particles versus the 200 nm ZnO particles? Explain why this is so based on your understanding of how the sunscreens work to block UV light.

   e. Is there any difference in how the two kinds of UV light interact with the sunscreens? Explain why this is so based on your understanding of how the sunscreens work to block UV light

3. Select the visible light option and play the animation for each of the sunscreen conditions. What happens to the visible light in each animation and what does the observer see?

   a. Skin without any sunscreen

   b. Skin with 200 nm ZnO particles sunscreen

   c. Skin with 30 nm ZnO particle sunscreen

4. What determines what the observer sees? (Do they see the skin or the sunscreen? What color do they see?)

5. How does scattering affect what the observer sees?

6. What variables don't change between the two animations with sunscreens?

7. What variable determines if the visible light scatters or not?

8. What would happen if we applied the large particle sunscreen in a layer only half as thick as the one shown? How would this affect its appearance? How would it affect its UV blocking ability?

9. What would happen if the observer (eye) moved 3 steps to the left to look at the skin?

10. When we make a model (such as these animations) we make tradeoffs between depicting the phenomenon as accurately as possible and simplifying it to show the key principles involved.

a. Are the different elements of the animation drawn on the same size scale? If not, which ones aren't? How do these affect the animation's ability to depict the scattering mechanism? Which elements in the animation are really on or close to the nanoscale? Which are on the macroscale? Which are on the cosmic scale?

b. What are some other ways these animations have simplified the model of the real world situation they describe?

c. What are some of the benefits of making a simplified model? What are some of the drawbacks?

Name_____ Date_____ Period _____

Reflecting on the Guiding Questions: Student Worksheet

Think about the activity you just completed. What did you learn that will help you answer the guiding questions? Jot down notes in the spaces below.

1. What are the most important factors to consider in choosing a sunscreen?

What I learned in this activity: What I still want to know:

2. How do you know if a sunscreen has "nano" ingredients?

What I learned in this activity: What I still want to know:

3. How do "nano" sunscreen ingredients differ from most other ingredients currently used in sunscreens?

What I learned in this activity: What I still want to know: