SMITHSONIAN DATA LABS
Answer Key
SPECTRUM LAB

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Module 1: Light ANSWER KEY

Light in Different Professions

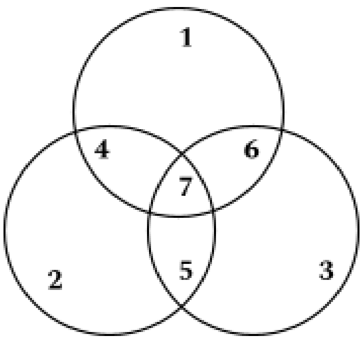
Your interests. Of the different professions featured in the slideshow, which are you most curious about? What questions do you have about how that field uses light?

Answers will vary.

Color Filters

Consider the 3 intersecting colored circles shown on the screen

Part 1: Predictions



Do **NOT** look through any of the colored gels yet!

a. Predict what you will see when you look through the **red-colored gel** at the 3 intersecting colored circles on screen. In the diagram below, color in (or write the name of the color) each of the 7 sections to represent how you think the onscreen image will look through the red gel:

1	
2	
3	
4	
5	
6	
7	

Student answers will vary, and that is ok.

The following are common misconceptions:

- that the red filter will "color everything red;"
- that the filters will behave like mixing paints so that looking through red will make the green appear brown and blue appear purple; or
- that the red filter blocks red light so the red circle will disappear.

b. Share your reasoning. How did you determine which parts of the circles would be visible and what colors the different parts of the circles would appear?

Student answers will vary, and that is ok.

Part 2: Investigation

you can **NOW** look through the gels:

c. What did you actually see when you looked through the red gel? How did it compare with your prediction?

Regions 1, 4, 6, and 7 (the top circle) look red. The other regions disappear or look very dim.

d. Describe what you think is happening, given the colors you saw through the red gel:

Student answers will vary, and that is ok.

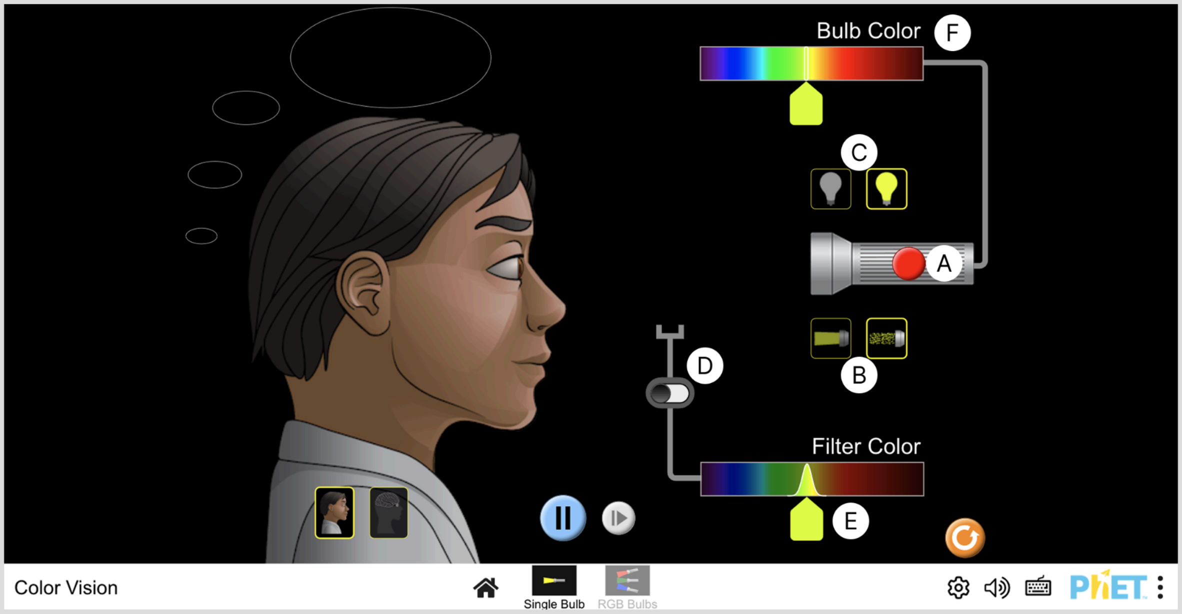
e. Discuss your ideas with your partner. What ideas did your partner add that seemed helpful?

Student answers will vary, and that is ok.

Photons & Color

Launch the Color Vision “Single Bulb” simulation from Physics Education Technology (PhET).

Part 1: Instructions



A Turn flashlight on/off

B Particle Modes: steady beam (left) or photons (right)

C White bulb (left) or colored bulb (right)

D Toggle filter on/off

E Change filter color slider

F Change bulb color slider

Choose **Single Bulb** and do the following:

1. Turn on the flashlight (red button). (A)

   Free-explore the interactive for a couple of minutes. Try different modes and turn on different combinations of bulb color and filter color.

Investigate what makes up **WHITE** light and what colored filters do.

2. Choose the particle mode for the light (underneath the flashlight, with photons instead of a steady beam). (B)

3. Choose a white bulb. (C)

4. Turn on a colored filter (there is a toggle in front of the mouth). (D)

5. Choose a red color for the filter. (E)

Investigate how colored filters behave with single-colored light sources.

6. Choose the light bulb that opens Bulb Color. (C)
7. Switch Bulb Color to a blue light. What happens to the light particles? (F)
8. Change the light to red, similar to your filter color. What happens to the light particles? (F)
9. Change the light bulb to the white one. What happens to the light particles of different colors? (C)

Part 2: Reflection Questions

Describe what makes up white light.

White light is what you get when light of all other colors is mixed together.

(You can actually make white light from mixing just red, green, and blue light, but students might not necessarily know that at this point).

Describe what a red filter does.

A red filter allows red light to pass through. Light of other colors is blocked (absorbed) and can't pass through.

Describe what happens if you put a RED filter in front of a GREEN light source.

A red filter allows red light to pass through. Green light will not pass through the red filter, so the viewer would see no light.

Helpful Information: Photon Theory of Light

In this module, we'll use the **Photon Theory** of light. Light is made of photons, which behave like waves in some situations and like particles in others. For simplicity, we will refer to photons as particles of light. The photon model—in which each photon is associated with a very specific color of light—will help us make sense of all the observations made throughout these lessons.

A prism can separate light from the Sun into all the colors of the rainbow—red, orange, yellow, green, blue, indigo, and violet—because sunlight is made up of photons of those specific colors.

The color receptors in human eyes respond to photons of all these individual colors, meaning, for example, we would perceive a stream of yellow photons as being yellow in color. Our eyes respond most strongly to red, green, and blue photons, and all other colors of light can also be made from different combinations of red, green, and blue light.

Color Mixing

Color-Mixing

You can mix 3 colors of light (red, green, and blue) to make any other color, similar to how you can mix red, yellow and blue paint to make any color. However, light colors mix very differently than paint colors, so **don't be surprised that color combinations don't behave as you expect**.

Part 1: Instructions

1. Switch to the **RGB Bulbs** simulation to explore how light colors mix.
2. Experiment with the RGB (red, green, and blue) lights in different amounts to make different colors. Try turning on two at a time, or three at a time but at different levels. Then try to make the following colors.

For each color, make a note in the table below for each R, G and B whether the bulb was OFF (**O**), or on at low (**L**), medium (**M**), or high (**H**) power. (You don't have to be very precise here).

What combinations of RGB lights make:

Yellow	R	H	G	H	B	O
Magenta (bright reddish purple)	R	H	G	O	B	H
Cyan (bright greenish blue)	R	O	G	H	B	H
Orange	R	H	G	M	B	O
White	R	H	G	H	B	H

Fun facts:
Most computer screens are made up of tiny light bulbs (called light-emitting diodes, or LEDs) that emit red, green or blue light.

If you have ever done any web design, you might be familiar with the hexadecimal color system. Hexadecimal codes specify to the computer the amounts of red, green, and blue light to display on each pixel on the screen.

Part 2: Reflection

Imagine you are looking at a source that is emitting yellow light. There are at least two possible combinations of one or more photon colors that would cause your eye to observe the source as yellow in color.

Identify those two combinations here.
Review the Photons and Color section if you're feeling stuck.

1.	The source of yellow light could be emitting yellow photons.
2.	The source of yellow light could be emitting a mix of red and green photons.

More on Color

The color of an object is determined by the mix of colors that it sends to your eye (either through emission, reflection, or transmission). For example, a green leaf looks green because it **reflects** green photons and **absorbs** photons of other colors. A white wall **reflects** photons of all colors, which together make white. A black shirt **absorbs** photons of all colors, which may make you feel overly hot on a sunny summer day.

Explore each of these concepts in the next section.

Behaviors of Light

Relevant Vocabulary

Emission. **When photons (light) are given off by an object**
(like the Sun or a light bulb shining)

Reflection. **When traveling photons (light) strike and then bounce away from an object**
(like a mirror or the surface of a lake)

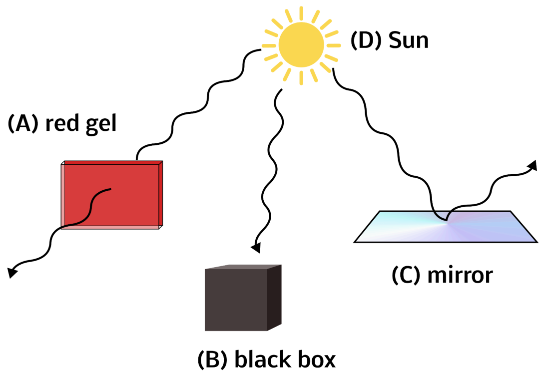
We usually associate reflection with smooth surfaces like a mirror, but photons can also reflect off rough surfaces, which tend to bounce photons in different directions. This is known as **scattering**.
(like sunlight's blue photons bouncing off molecules in our atmosphere, or green photons from a leaf).

Absorption. **When photons (light) are stopped by an object and their energy is taken in**
(like black paint that gets hot in sunlight, or leaves on a tree that absorb red and blue photons to power photosynthesis)

Transmission. **When traveling photons (light) pass through an object without being reflected or absorbed**
(as through glass, water, or air)

NOTE: Most objects interact with light in more than one way, and they often interact differently with different wavelengths of light. For example, tree leaves absorb red and blue photons and reflect green photons.

Part 1: Slideshow



Consider the diagram below. Circle or highlight the letters of the objects that are associated with the light phenomena listed. (Some may have more than one answer.)

1. Emission	A	B	C	**D**
2. Reflection	A	B	**C**	D
3. Absorption	**A**	**B**	C	D
4. Transmission	**A**	B	C	D

Part 2: Recap

Let's return to the three overlapping colored circles you viewed at the beginning of class. Use all four light behaviors (emission, reflection, transmission, absorption) to describe what is happening when you look at them through the red gel. You may discuss your ideas with a partner, as a class, or in small groups, as directed by your teacher.

The computer monitor or classroom projector is emitting light.
The top circle is emitting red photons. The bottom left circle is emitting blue photons. The bottom right circle is emitting green photons.
(Bonus: The overlap of all 3 circles is white because Red + Blue + Green make white.
The overlap of the red + green = yellow; blue + green = cyan; blue + red = magenta.)

The red gel transmits the red photons, and our eye sees the red circle. The red gel absorbs the blue and green photons, and the blue and green circles appear dark.
(Bonus: The red gel also has a shiny smooth surface, so at some angles light reflects off the surface of the gel.)