Level A Investigations

A-1 Introduction to Light

How can you make light and how can you study it?

Students learn how light is produced by examining the effects of adding light energy to glow-in-the-dark material. They also discover that certain colors of light have more energy then others.

A-2 Color

What happens when you mix different colors of light?

All the colors of visible light can be created artificially using a combination of three primary colors: red, blue and green. In this Investigation, students will use a white light source and color filters to discover what happens when you mix different colors of light. They will also learn how color filters work.

A-3 Rules of Reflection

How does light reflect?

Students plot a beam of light as it reflects off of a mirror. They learn the terminology associated with studying rays of light. Next, they measure the angle of reflection and compare it to the angle of incidence.

Level B Investigations

B-1 Seeing an Image

What is magnification and how do you plot a reflected image?

Students learn a method for finding the magnification of a single lens. In part two of the Investigation, students learn how to predict where the image in a mirror appears by tracing the incident and reflected rays of light from a laser.

B-2 Polarization

How does a polarizing filter work?

In this Investigation, students model the transverse wave motion of light using a rope. They describe the polarization of transverse waves and demonstrate the polarization of light using polarizing filters. Finally, they analyze practical applications of polarization.

B-3 Optical Technology

How are optics used in everyday life?

Fiber optics work because light which enters the fiber optic at an angle greater than the critical angle will be reflected back into the fiber instead of being refracted as it passes out of the fiber. In this Investigation, students will find the critical angle for a glass prism.

B-4 Ratios

How can a laser be used to measure distance?

Laser beams are often used to calculate precise distances that would be difficult to measure directly. In this Investigation, students will discover how a laser beam and a diffraction grating can be used together as a measuring tool.

Level C Investigations

C-1 Light and Color

What are the properties of light?

In this Investigation, students use photo luminescence to demonstrate the different energy content of red and blue light. A diffraction grating splits light up into its spectrum.

C-2 The Law of Reflection

Why do we see an image in a mirror?

This Investigation uses a laser beam to observe and measure precisely how light reflects. Students measure the angle of incidence and reflection and deduce the law of reflection.

C-3 Refraction and Snell's Law

How do glass and other materials bend light rays?

Students explore the refraction of light with a laser and a prism. By tracing the laser through the prism, students observe how light refracts as it crosses boundaries between materials. By tracing the rays on graph paper, students test Snell's law and measure the index of refraction of glass. At the end of the Investigation, students observe the critical angle by causing the laser beam to be internally reflected withing the prism.

C-4 The Convex Lens

How does a lens work?

Students work with a flat converging lens in this Investigation. They first plot the path of a light beam from a laser through the lens and identify the focal point and focal length. The beam from the laser represents a single light ray going through the lens. By using the laser to trace rays from an arrow drawn on paper, students learn how real images form where many rays from a point on an object meet again. The last part of the Investigation demonstrates spherical aberration and shows how spherical aberration can be corrected using apertures or different lens shapes.

C-5 Geometric Optics

Can you tell what type of image a lens will make?

Students plot rays to analyze the images formed by a convex lens and determine the focal length of their lens using the image from a distant object. Students then use the lens a as a magnifying glass, creating a virtual image and analyzing its properties. In the last part, students create real images on a screen with the lens. They observe that red and blue light form images in slightly different places.

C-6 The Thin Lens Equation

Can you analyze lenses without drawing rays?

In this Investigation, students use the thin lens equation to predict the location of the images formed by a single lens and then a pair of convex lenses. The prediction is tested with actual lenses.

C-7 Wave Properties of Light

How do we know light is a wave?

Students use a diffraction grating and polarizer to perform experiments that demonstrate the wave nature of light. Students work with the diffraction by using the wavelength of red laser light to measure the spacing of the grooves in the grating, and the pits on an audio CD. Waves on a spring are used to demonstrate polarization. Polarization is used to explain the observed effects of polarizers on transmitted light.

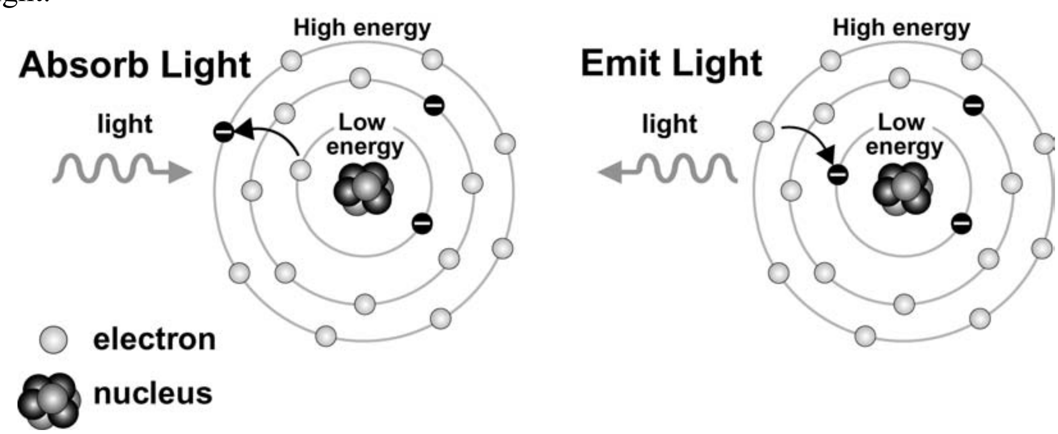
Question: What are the properties of light

In this Investigation, you will:

1. Show that white light can be made from red, green, and blue
2. Observe evidence that light of different colors has different energy content

1 How is light produced

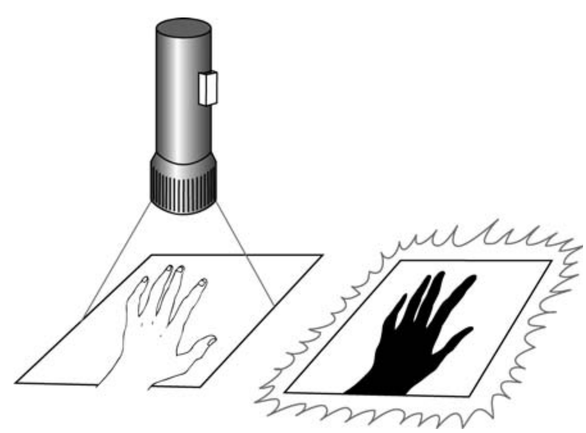
Almost all the light you see is produced by atoms. When atoms absorb energy, electrons rise to higher energy levels. When the electrons fall back to their lower energy state, they may release energy in the form of light.



In some elements it takes time for the energized electrons to fall back and give up their energy. These elements store energy and give off light slowly over a period of time. This is how glow-in-the-dark material works. Embedded in the material are atoms of the element phosphorus. When light energy hits the phosphorus atoms, some of the electrons absorb energy. When the electrons fall back, they release the stored energy and the material glows. The glow stops when all the electrons have returned to the lowest energy level. The process is called **photoluminescence**. The word "photo" means light and the word "luminescence" means glowing.

2 Examine the effects of light on glow-in-the-dark material

1. Uncover the glow- in-the-dark material (on the underside of the optics board) in a darkened room.
2. Cover part of the material and turn the lights back on, or shine a flashlight onto the material.
3. Turn off the light source, remove the covering, and record your observations.
4. Expose the material to light completely uncovered.
5. Turn off the light and wait a minute, then place your hand over part of the material.
6. Remove your hand, and then record your observations.



3 Recording and analyzing your results

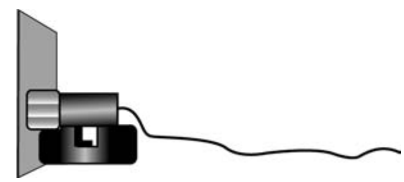
In answering these questions, think in terms of light and energy. Explain what happens to the energy in each of these situations.

a. What happened when the light was not allowed to strike the glow-in-the-dark material? Explain.

b. What happened when your hand was allowed to rest on the glow-in-the-dark material? Explain.

4 Examining the effect of different colors of light

In part 2, you used a source of white light to add energy to the phosphorus atoms in the glow-in-the-dark material. White light is a mixture of all colors of the rainbow. In this section, you will determine what happens when just one color of light is used to add energy to the phosphorus atoms.

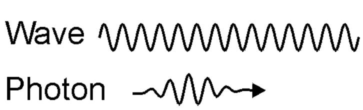


1. In a darkened room, allow the glow-in-the-dark material to stop glowing.
2. Switch on the red LED and shine it on the glow-in-the-dark material from a distance of about 10 centimeters. Wait 15 seconds, then take the LED away and record your observations.
3. Try the same experiment again with the red LED 5 centimeters away, then again with the LED held right up against the surface. Decreasing the distance increases the intensity of the light without changing its color.
4. Repeat the procedure with the green LED. Record your observations.
5. Repeat the procedure with the blue LED. Record your observations.

5 The quantum theory of light

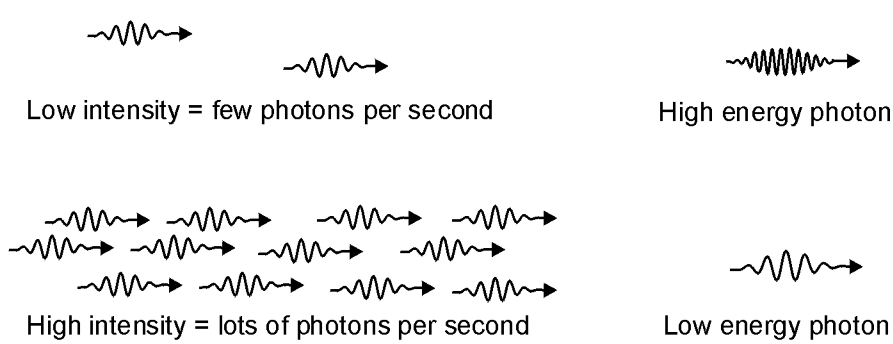
A **photon** is a small quantity (like a particle) of light. You can think of a photon like a short packet of a wave. The *intensity* of light describes how many photons per second are produced (or absorbed). The *color* of each photon depends on its energy. Different colors of light are produced by photons with different energies. High energy photons have shorter wavelengths than low energy photons.

What is a photon?



A photon is like a short burst of a wave

The difference between intensity and energy



In order to glow, an electron in a phosphorus atom must first absorb energy from a photon of light. One of the predictions of the quantum theory is that electrons cannot have any energy, but can have only the specific energies corresponding to the energy levels in a particular atom. That means a photon must have enough energy to boost the electron up one whole level to be absorbed. If the photon does not have enough energy, the electron cannot absorb it and the phosphorus atom cannot glow.

6 Thinking about what you learned

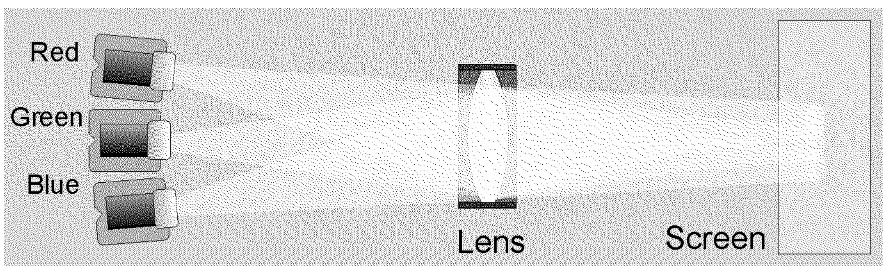
a. Based on the observations you made in part 4, what color light has the highest energy? What color light has the lowest energy? Your answer should state how your observations support your conclusion.

b. Intuitively you might think the more intense you shine the light, the more brightly the phosphorus should glow. Explain how your observations either support or refute this hypothesis.

c. How does what you observed support the quantum theory of light and atoms? HINT: What would have happened if electrons were free to absorb any energy rather than just certain energies?

d. Einstein received the Nobel prize for correctly explaining the results of an experiment much like the one you just did. Find out what Einstein's brilliant insight was and identify the experiment that Einstein correctly explained.

7 Mixing primary colors of light



1. For this Investigation, you will use red, blue, and green LEDs (light emitting diodes). Attach each LED to the power supply and plug in the whole assembly.
2. Place the three LEDs next to each other side by side on one edge of the optics table. Set one of the lenses in the middle. Set the screen at the opposite edge from the LEDs. You should see three spots of color in the screen corresponding to the red, green, and blue LEDs.
3. Move the lens and screen to make the three spots overlap and observe the colors on the screen.

8 Explaining what you see

a. What color do you see when you mix red and green light?

b. What color do you see when you mix red and blue light?

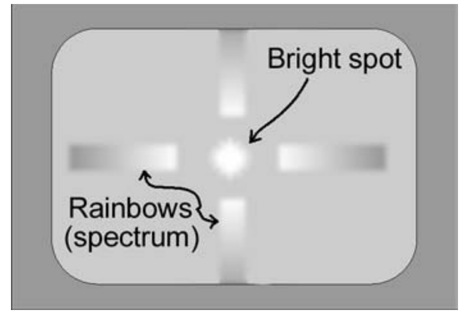
c. What color do you see when you mix blue and green light?

d. What color is produced when all three colors of light are equally mixed?

e. Explain why white light was able to make the phosphorus glow in the dark?

9 Breaking apart light

Most of the light we see is made of a mixture of many different colors. The diffraction grating glasses can separate out the different colors. If you look at a bright light through a diffraction grating you see rainbows on all sides. The rainbows spread out all the colors that are present in the light coming through the bright spot in the center. Technically, the rainbows are called a **spectrum**. A spectrum shows what different colors of light make up a particular sample of light.



You have three different sources of colored light. The green light looks green; but just how “pure” is the green? In this part of the Investigation you will examine the light produced by each colored LED, and learn how a **color filter** works. You will use the diffraction glasses to make your observations. The diffraction glasses allow you to see the different colors of the spectrum that a light source produces.

For each observation, look at the spectrum on the sides of the bright LED to observe the mixture of colors.

1. Look at the red LED through the diffraction glasses.
2. Look at the blue LED through the diffraction glasses.
3. Look at the green LED through the diffraction glasses.
4. Unscrew the color filter from one of the color LEDs. Look through the diffraction glasses at the light produced by the white LED.
5. Shine the red laser onto the screen. Look at the spot on the screen through the diffraction glasses. DO NOT LOOK DIRECTLY AT THE LASER BEAM.

10 Explaining what you see

a. Describe the similarities and differences you observed in the spectra from the red, blue, and green LEDs. You may want to use colored pencils to sketch the colors in the spectrum.

b. Describe what you saw looking at the white LED. Compare the spectrum from the white LED with the spectra from red, green and blue. You may want to use colored pencils to sketch the colors in the spectrum.

c. Describe what you saw looking at the laser spot. How is the spectrum of the laser different from the red LED?

d. Based on your observations, explain how the colored filters transform the white light of the LEDs inside the lamps into red, green, and blue.

Name:

C-1 Light and Color

C-1

Question: What are the properties of light

1 How is light produced

There are no responses required for Part 1.

2 Examine the effects of light on glow-in-the-dark material

1. Uncover the glow- in-the-dark material (on the underside of the optics board) in a darkened room.
2. Cover part of the material and turn the lights back on, or shine a flashlight onto the material.
3. Turn off the light source, remove the covering, and record your observations.

4. Expose the material to light completely uncovered.
5. Turn off the light and wait a minute, then place your hand over part of the material.
6. Remove your hand, and then record your observations.

3 Recording and analyzing your results

a. What happened when the light was not allowed to strike the glow-in-the-dark material? Explain.

b. What happened when your hand was allowed to rest on the glow-in-the-dark material? Explain.

4 Examining the effect of different colors of light

1. In a darkened room, allow the glow-in-the-dark material to stop glowing.
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4. Repeat the procedure with the green LED. Record your observations.
5. Repeat the procedure with the blue LED. Record your observations.

5 The quantum theory of light

There are no responses required for Part 5.

6 Thinking about what you learned

a. Based on the observations you made in part 4, what color light has the highest energy? What color light has the lowest energy? Your answer should state how your observations support your conclusion.

b. Intuitively you might think the more intense you shine the light, the more brightly the phosphorus should glow. Explain how your observations either support or refute this hypothesis.

c. How does what you observed support the quantum theory of light and atoms? HINT: What would have happened if electrons were free to absorb any energy rather than just certain energies?

d. Einstein received the Nobel prize for correctly explaining the results of an experiment much like the one you just did. Find out what Einstein's brilliant insight was and identify the experiment that Einstein correctly explained.

7 Mixing primary colors of light

There are no responses required for Part 7.

8 Explaining what you see

a. What color do you see when you mix red and green light?

b. What color do you see when you mix red and blue light?

c. What color do you see when you mix blue and green light?

d. What color is produced when all three colors of light are equally mixed?

e. Explain why white light was able to make the phosphorus glow in the dark?

9 Breaking apart light

There are no responses required for Part 9.

10 Explaining what you see

C-1

a. Describe the similarities and differences you observed in the spectra from the red, blue, and green LEDs. You may want to use colored pencils to sketch the colors in the spectrum.

b. Describe what you saw looking at the white LED. Compare the spectrum from the white LED with the spectra from red, green and blue. You may want to use colored pencils to sketch the colors in the spectrum.

c. Describe what you saw looking at the laser spot. How is the spectrum of the laser different from the red LED?

d. Based on your observations, explain how the colored filters transform the white light of the LEDs inside the lamps into red, green, and blue.

Questions

1. Electrons with higher energy are located:
   a. father from the nucleus of an atom
   b. closer to the nucleus of an atom
   c. in the nucleus of an atom
   d. in waves of light emitted from the atom.
2. Would it be possible to have a glow in the dark material that would 'charge up' with red light then emit blue light as it glowed? Your answer should give a physical reason supporting your conclusion.

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3. Which of the following best explains what happens when white light passes though a red plastic filter.
   a. The plastic transforms all wavelengths to the wavelength of red light.
   b. The plastic absorbs most of the red light.
   c. The plastic heats up until it glows red.
   d. The plastic absorbs most of the green and blue light.
4. Describe how you could mix red and green light to make orange rather than yellow.

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5. An experiment has two different light sources. One is very bright and makes blue light. The other is very dim and makes red light. Describe *two differences* between the two light sources in terms of the photon theory of light.

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6. Use the blue LED to make a glowing spot on the glow-in-the-dark material. Look at the glowing spot through the diffraction grating glasses. Describe the spectrum of light you see through the glasses.

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Extra space for notes:

Curriculum Resource Guide: Light and Optics

Credits

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