Name:

16.1 Properties and Sources of Light

Question: What are some useful properties of light?

1 Fooling the brain with light

a. Draw a sketch that uses lines to show how the light from the arrow on the paper reaches your eyes by reflecting from the mirror.

2 Seeing reflection and refraction at the same time

a. Draw a diagram showing the path of the light when you see the X.

b. Draw a diagram showing the path of the light when you see the O.

c. Is the image in the prism always reflected or refracted or can there be both reflection and refraction at the same time?

3 The speed of light

a. Measure the distance from the arrow you drew on the optics table to your eyes.

b. Calculate the time it takes light to travel this distance.

c. Calculate how far light would travel in one second.

4 The inverse square law and light from distant stars and galaxies

a. Suppose a star like the sun were a distance of 4×10^{16} meters away. What is the intensity of the light from that star that reaches Earth?

b. How much time did the light take to get from the star to Earth? As we look out into the universe, we are also seeing backward in time because the light from distant stars and galaxies has traveled many years before reaching human telescopes. Using this technique, we are able to see more than one billion years back in time.

c. A typical 100-watt light bulb makes about 20 watts of light and 80 watts of heat. Calculate the intensity of light from the bulb by using the light power (20 W) and the intensity formula. Repeat the calculation for a distance of 1 meter, 100 meters, and 500 meters away. A human eye is a very sensitive light detector; you can still see a 100-watt bulb at a distance of 500 meters.

Extra space for notes and performing calculations:

Name:

16.2 Color and Vision

Question: How do we see color?

1 Mixing primary colors of light

There are no questions to answer in Part 1.

2 Explaining what you see

Use Table 1 to record the answers to the following questions about your observations.

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?

Table 1: Mixing primary colors of light

LED color combination	Color you see
Red + Green	
Green + Blue	
Blue + Red	
Red + Green + Blue	

3 Breaking apart light

Safety Note: DO NOT LOOK DIRECTLY AT THE LASER BEAM.

Table 2: Examining light sources

Red LED	Green LED	Blue LED

White LED	Red laser spot

4 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 the spectrum you saw looking through the diffraction grating glasses at the spot made by the red laser on the screen. How is the spectrum of the red laser different from the spectrum of 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:

16.3 Photons and Atoms

Question: How does light fit into the atomic theory of matter?

1 How is light produced?

There are no questions to answer in Part 1.

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

There are no questions to answer in Part 2.

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

There are no questions to answer in Part 4.

5 The quantum theory of light

There are no questions to answer in 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 the light is that you shine, the more brightly the phosphorus should glow. Explain how your observations 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?

Name:

17.1 Reflection and Refraction

Question: How do we describe the reflection and refraction of light?

1 The law of reflection

Table 1: Angles of incidence and reflection

	Diagram #1	Diagram #2	Diagram #3	Diagram #4
Angle of incidence				
Angle of reflection				

a. Write down your own statement of the law of reflection, describing the relationship between the angle of incidence and the angle of reflection.

2 Refraction

There are no questions to answer in Part 2.

3 Tracing rays through the prism

There are no questions to answer in Part 3.

4 Finding the index of refraction

Table 2: Angles of incidence and refraction

	Angle/incidence	Angle/refraction
Going from air to glass		
Going from glass to air		

a. Draw the normals to the two faces of the prism the beam passed through. When light goes from a low-index (air) to a higher-index (glass) material, does it bend toward the normal or away from the normal?

b. When light goes from a high-index (glass) to a low-index (air) material, does it bend toward the normal or away from the normal?

c. Use the two normals and a protractor to determine the angles of incidence and refraction for both surfaces crossed by the light beam. Use Table 2 to record the angles.

d. Apply Snell's law to the light ray entering the prism. The incident material is air (n = 1); the refracting material is glass ($n = n_g$). Calculate the sines of the angles of incidence and refraction. Use your calculation to determine the index of refraction of glass (n_g).

e. Apply Snell's law to the light ray leaving the prism. Using the index of refraction for glass, predict what the angle of refraction should be when the laser beam goes from glass to air.

f. Compare your predicted angle of refraction to the angle you measured. Comment on any differences between your prediction and your measurement. Do your observations support Snell's law? Your answer should be supported by your observations of the laser beam.

5 The critical angle of refraction

There are no questions to answer in Part 5.

Name:

17.2 Mirrors, Lenses and Images

Question: How does a lens or mirror form an image?

1 The image in a mirror

There are no questions to answer in Part 1.

2 Refracting light through a lens

There are no questions to answer in Part 2.

3 Analyzing what you observed

a. Describe the path of the laser beam as it travels along the axis and through the lens. Compare the paths of the incident and the refracted rays.

b. Describe the path of the laser beam as it travels parallel to the axis and above or below the axis. Compare the paths of the incident and refracted rays.

c. The two refracted rays that you traced in Part 1 crossed the axis. Mark the axis where these rays crossed. This is the focal point for your lens. Due to imperfections in the lens, these two rays may not meet in exactly one point. In this case, choose the mid-point between the two points as your focal point.

d. Measure the distance between the focal point and the center of your lens. This distance is the focal length of your lens.

e. Label the focal point and focal length on your ray diagram.

4 Finding the image formed by a lens

There are no questions to answer in Part 4.

5 Characteristics of the image

a. Is the image larger or smaller? Calculate the magnification by dividing the length of the image by the length of the original arrow.

b. Is the image right side up or is it inverted?

c. Is the image closer to the lens than the original arrow or is it farther away?

6 The image from a single lens

a. Was the image created by a single lens smaller or larger than the object?

b. Was the image right side up or was it inverted?

7 Finding the magnification of a lens

Table 1: Magnification data for a single lens

Distance to paper (cm)	# of squares on the graph paper (unmagnified squares)	# of squares in the lens (magnified squares)	Magnification

Name:

17.3 Optical Systems

Question: How are the properties of images determined?

1 Projecting an image with a lens

Table 1: Image data for a single lens

Object dist. (cm)	Image dist. (cm)	Image orientation	Image height (mm)	Magnification

2 Analyzing what you observed

a. Make a scale drawing showing the positions of the object, lens, and screen. Measure and mark the near and far focal point of the lens. Draw an arrow for an object at the correct object distance from the lens corresponding to one of your experiments. Draw the three principle rays from the tip of the arrow using the rules above. The place where the rays meet is where the image forms.

b. Measure the image distance from your drawing and the height of the image. The height of the image is the length of the image arrow from the optical axis to the tip. Make a similar scale drawing for each of your experimental trials.

c. Record the theoretical image distance for each drawing in Table 2. Calculate and record the magnification, too. The magnification is the height of the image arrow divided by the height of the object arrow.

Table 2: Ray tracing analysis for a single lens

Object dist. (cm)	Image dist. (cm)	Image orientation	Image height (mm)	Magnification

d. How do your ray-tracing predictions compare with your actual measured images? Write one or two sentences comparing measured and calculated data.

3 Chromatic aberration

a. With a prism, you may have observed that red light and blue light are bent by different amounts. This is why prisms spread light into a rainbow. In a lens, the effect is called *chromatic aberration* and it affects the color in images formed by lenses. How does chromatic aberration explain the difference you saw in the image distances formed with red and blue light?

4 The thin-lens formula

There are no questions to answer in Part 4.

5 The image from a single lens

Table 3: Predicted and measured image distances

Object distance (cm)	Focal length (cm)	Predicted image distance (cm)	Measured image distance (cm)

a. How close did your prediction of the image come to the actual image? Answer with a percentage.

b. Use the thin-lens formula to calculate the image distances for the previous experiments you did in Part 1 of this Investigation (Table 1). Do the calculations agree with the measurements?

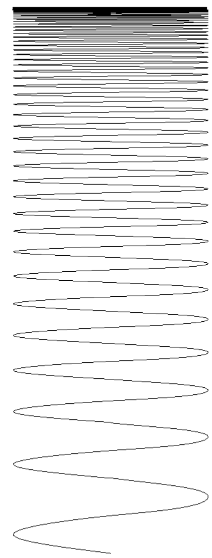
Name:

18.1 The Electromagnetic Spectrum

Question: What is the electromagnetic spectrum?

1 Researching your electromagnetic wave

Your teacher will assign your group one type of electromagnetic wave that you will research using the Internet or reading. You will construct a poster displaying the information you gather about your type of wave. You will also present what you have learned to your classmates. All of the posters made by the class will be displayed in the order of the waves that make up the electromagnetic spectrum.



Your research should include the answers to the following questions. Do not limit yourself to these questions; include other interesting information as well. Record the sources you use for a bibliography.

1. What is the range of wavelengths for your type of wave?
2. What is the range of frequencies?
3. What is the source of the wave?
4. Who discovered this type of wave and when?
5. Are these waves easily blocked or can they pass through objects?
6. Do the waves have an effect on people? Are they harmful?
7. Discuss the uses for the waves. These may include inventions that we use in our everyday lives, medical uses, or ways scientists use the waves for research. You should spend the greatest amount of time on this part of your research.

2 Sharing your information

Organize your information on a poster. You should include drawings where they are appropriate. Make a bibliography of your sources and put it on the back of your poster.

Present what you learned to the other groups in your class. You should be able to discuss the uses for your type of wave.

Listen to the presentations made by other groups. Which type of wave do you think is the most useful to us? Why?

Extra space for notes and performing calculations:

Name:

18.2 Interference, Diffraction, and Polarization

Question: What are some ways light behaves like a wave?

1 How a diffraction grating works

There are no questions to answer in Part 1.

2 Measuring the wavelength of laser light

a. Use the value for the spacing of the grooves on the diffraction grating from your instructor for *d*. Use the grating formula ($\lambda = dw \div L$) to calculate the wavelength of the laser light (λ).

b. Does the value of wavelength of the laser fall within with the range of wavelengths that appear red to the human eye?

3 The spectrometer

Table 1: Spectrometer observations

Apparent color	Observed range of wavelengths	Appearance of lines

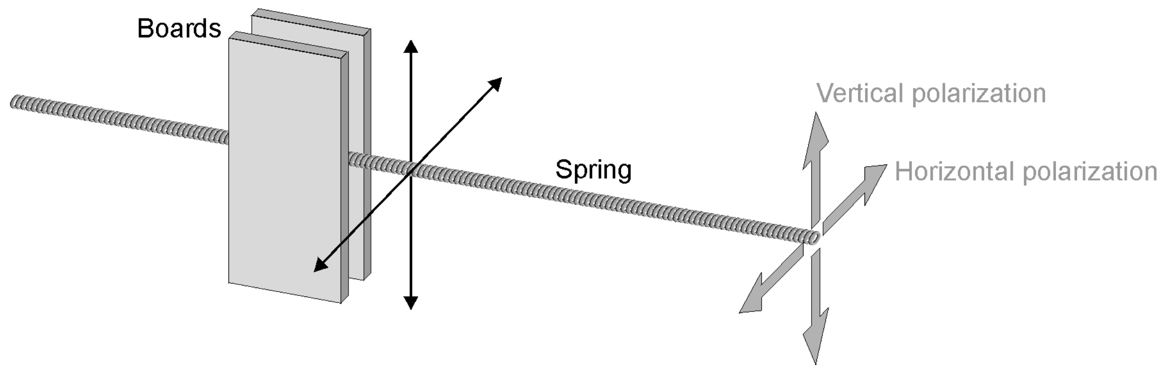
4 Polarization of a transverse spring wave

There are no questions to answer in Part 4.

5 Describing and applying what you see

a. Describe the motion of the spring using the terms *horizontal polarization* and *vertical polarization*. Your description can be in words, diagrams, or both.

b. Suppose you try to sandwich your spring wave between two boards. What happens to the waves if you make them pass through the narrow space between the boards? If the boards were oriented like the picture below, discuss how the two different polarizations of waves would behave. Which would get through the slot and which would be blocked?



c. Describe the polarization of water waves. Are there two polarizations (like the spring) or only one? What is it about a water surface that makes it different from a spring?

6 The polarization of light

There are no questions to answer in Part 6.

7

How do you explain what you see?

a. The light from the sun (or a lamp) is not polarized, meaning it is a mixture of light that is polarized equally in all directions. Explain why the light is reduced passing through one polarizer.

b. When the light passes through the first polarizer, it becomes polarized. We say light is polarized when it consists of only one polarization. Explain why rotating the second polarizer changes the amount of light you see coming through.

c. The glare from low-angle sunlight reflecting from water and roads is polarized in the horizontal direction. Ordinary sunlight is not polarized. Explain how polarizing sunglasses can stop most of the glare but still allow half the regular (unpolarized) light to come through.

Extra space for notes and performing calculations:

Name:

18.3 Special Relativity

Question: What are some of the implications of special relativity?

1 When does special relativity become important?

a. A high-performance aircraft flies at a speed of 1,340 m/sec, or 4 times faster than the speed of sound (340 m/sec). At this high speed, will the effects of time dilation be perceived by a person with an ordinary watch?

b. A rocket traveling to Mars must have a speed greater than the minimum speed required to break Earth's gravitational attraction. This minimum speed is called the escape velocity. Use research to find Earth's escape velocity. Is the escape velocity fast enough that relativity must be considered for normal purposes such as synchronizing two clocks?

c. The numbers in Table 1 were calculated using a formula proposed by Einstein. Research the formula to identify what the variables mean.

2 Relativity and frames of reference

a. There are two reference frames important to understand the motion of the darts. What are they and what are their relative velocities?

b. What is the speed of the first dart relative to the train?

c. What is the speed of the first dart relative to the ground?

d. How fast does the second dart approach the dart board on the pole?

3 The equivalence of mass and energy

a. Calculate the amount of energy used by a 100 W light bulb that is left on continuously for one year.

b. Suppose you could extract all of the energy in 1 kg of mass with 100 percent efficiency. How long could this amount of energy keep the 100 W light bulb lit. Give your answer in years.

c. Nuclear reactors convert a tiny fraction of the mass of uranium atoms into energy. Assume that 0.07% of the mass of uranium is converted to energy. How much energy do you get from 1 kg of uranium in a nuclear reactor?

d. To appreciate the energy obtained from a kg of uranium, estimate the electric power used by a city of one million people. Assume that each person in the city uses an amount of electricity equal to 10 light bulbs that use 100 watts each. Calculate the total energy used by multiplying the total power in watts by the number of seconds in one year (you will get a very large number).

e. How many kilograms of uranium must be used in a nuclear reactor to produce this amount of energy?

f. One barrel of ordinary gasoline yields about 5×10^9 joules of energy. Calculate how many barrels of gasoline are required to produce the energy you estimated in Part d.

Extra space for notes and performing calculations: