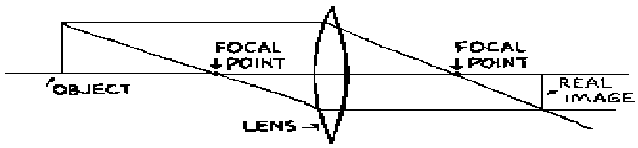
Wave Phenomena

A Physics Unit at Ruamrudee International School

In this unit you are going to study the various theories that have been offered to explain the nature of light; later you will be introduced to the notion that light is both a wave and a particle. Hopefully from this study about the history of these ideas you will begin to see how preconceived notions about the WAY THINGS SHOULD BE can often present obstacles to scientific progress.

With your understanding about the nature of light, you will look at how light behaves when it interacts with matter. The interactions you will be studying are those of reflection, refraction, diffraction and interference. In your studies, you will be assuming that light travels in straight lines called rays. Rays are at right angles to the wave front and indicate the direction of motion of the wave. Next you are going to study the topic of Optics and by doing so you will hopefully begin to understand how images are produced by lenses, rainbows, mirrors and other light enhancers.



The laws of reflection, and refraction, as well as the principles of the reflecting telescope, the formation of images by lenses and the dispersion of light by prisms are the topics of this unit. This study is called geometric optics. Keep your eyes open!

When you complete the activities in this unit, you should with 80% accuracy be able to:

12-1 **Describe** the *reflection* and *transmission* of one-dimensional waves at a boundary between two media.

12-2 **State** Huygens' principle.

12-3 **Apply** Huygens' principle to two-dimensional plane waves to show that the angle of incidence is equal to the angle of reflection.

12-4 **Explain** *refraction* using Huygens' principle

12-5 **Define** *refractive index*

12-6 **Define** the terms *principal axis, focal point, focal length, linear magnification* and **Construct** *ray diagrams* to locate images formed by lenses.

12-7 **Explain** the difference between a real and a virtual image.

12-8 **Explain and Discuss** qualitatively, using Huygens' principle, the diffraction of waves by apertures and obstacles.

12-9 **Describe** examples of diffraction.

12-10 **Construct** ray diagrams to locate images formed by mirrors.

12-11 **Determine** the nature of images formed by different types of lenses with different object-to-lens separations

12-12 **Solve problems** using the following equations and/or their derivatives:

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$
(*Lens Makers Equation*)

$$\frac{h_i}{h_o} = m = \frac{d_i}{d_o}$$
(magnification)

$$n_1 \sin i_1 = n_2 \sin i_2$$
(Snell's Law)

$$n_s = \frac{c}{v_s}$$
(Index of Refraction)

$$\sin i_c = \frac{1}{n_i}$$
(Critical Angle)

How to make your life as a student easier.

In General

Read the unit objectives.

Compare the objectives to the activities you're going to do.

Read the chapter title, the **bold** print and the section headings.

Doing the Activities

Read and understand how to do the activity before you try to do it.

Find the objectives that the activity is teaching.

When all else fails, *read the book*!

Identify and learn the vocabulary

Tips

Work with your group.

Don't PROCRASTINATE!

Use all of the available resources.

Have fun and enjoy learning!

Instructional Activities

Text Reference: Chapters 13 – 16

1. SQ3R for understanding
2. Lab: Mirrors and Lenses
3. Activity: Ray-Tracing (Mirrors)
4. Physlet: Exploration 33.3 (Ray Diagrams)
5. Holt Physics-Reflection
6. Activity: Ray-Tracing (Lenses)
7. Concept Devel. 29-3 (Refraction)
8. Physlet: Illustration 35.1 (Lenses)
9. Concept Devel. 29-4 (Refraction)
10. Holt Physics-Refraction
11. Lab: Mirrors & Lenses Investigation
12. Snell's Law
13. Drawing Index of Refraction Diagrams
14. Concept Devel. 30-2 (Lenses)
15. Diffraction Activity
16. Lab: Measuring by Diffraction
17. Diffraction & Interference problems

Practice Questions & Problems / Homework

Chapter 15	Homework Set #1	pgs. 587–589	1–3, 10–14, 24 - 26
Chapter 16	Homework Set #2	pgs. 620–621	1–4, 9, 10, 12–15
Chapter 14	Homework Set #3	pgs. 550-552	14–16, 34–36

Unit Review

Unit Test ___________________

We are all fellow passengers on a dot of earth. And each of us, in the span of time, has really only a moment among our companions.
Ń Lyndon Baines Johnson

He who can no longer pause to wonder and stand rapt in awe, is as good as dead; his eyes are closed.
Ń Albert Einstein

Mirrors and Lenses

Discussion

The behavior of mirrors is based on the Law of Reflection, while the behavior of lenses depends on what we know about what happens when light travels from one medium to another, which is called refraction.

Using the available equipment, you are going to investigate the ideas of *focal point*, *real and virtual images*, *magnification* and how they relate to *concave and convex mirrors and lenses*.

Procedure

Part 1 - Mirrors

1. Determine the *focal length* of the concave mirror as demonstrated by your instructor.
2. Once you know the *focal length* of the mirror, use this information to complete the following charts:

Nature of Image – Concave Mirror			
Position of Object	**Real or Virtual?**	**Magnified?**	**Inverted or Erect?**
Beyond *f*			
At *f*			
Within *f*			

Nature of Image – Convex Mirror			
Position of Object	**Real or Virtual?**	**Magnified?**	**Inverted or Erect?**
Beyond *f*			
At *f*			
Within *f*			

Part 2 - Lenses

3. Determine the *focal length* of the concave lens as demonstrated by your instructor.
4. Once you know the *focal length* of the lens, use this information to complete the following charts:

Nature of Image – Converging Lens			
Position of Object	**Real or Virtual?**	**Magnified or Reduced?**	**Inverted or Erect?**
Beyond 2*f*			
At 2*f*			
At *f*			
Within *f*			

Nature of Image – Diverging Lens			
Position of Object	**Real or Virtual?**	**Magnified or Reduced?**	**Inverted or Erect?**
Beyond 2*f*			
At 2*f*			
At *f*			
Within *f*			

Conclusion

Discuss and analyze what you have seen happening in this experiment. Include in your comments what error(s) were made and what affect that each error has on the results.

Concave and Convex Mirrors & Lenses

An Investigation by computer simulation

Purpose: This experiment will let you "play" with how images are formed when light interacts with mirrors and lenses. *To get the most out of this experiment you need to pay attention* ..... to how the images are formed as you move the object closer or farther away from the mirror or lens.

Procedure: Use the appropriate **Physlet** to investigate each of the situations described below. Draw a diagram, to illustrate the solution to each situation. Have your teacher approve the drawings when you are finished.

Situation #1 Use a convex lens to create a real image that is real, inverted and approximately one–half the height of the object.

Situation #2 Use a convex lens to create a virtual image that is virtual, erect and enlarged.

Situation #3 Use a convex lens to create a real image that is real, inverted and formed when the object is half–way between **2f** and **f**.

Situation #4 Use a concave lens to create a virtual image that is virtual, erect, reduced and almost at the focal point.

Situation #5 Use a convex mirror to create a virtual image that is erect, reduced and approximately half–way between **f** and the mirror.

Situation #6 Use a concave mirror to create a real image that is formed when the object is at **CC**.

Situation #7 Use a concave mirror to create a real image that is real and is larger than the object.

Situation #8 Use a concave mirror to create a virtual image.

Questions: **a)** What do the symbols **f**, **CC**, and **2f** mean ?

b) Compare and contrast how images are formed by concave and convex lenses.

c) Compare and contrast how images are formed by concave and convex mirrors.

Measuring by Diffraction

A Physics experiment

Problem

How can the wave nature of light be used to measure the thickness of a human hair?

Discussion

Diffraction is the bending of light around the edges of barriers. It is well known that when light falls on a small opening a diffraction pattern is produced. It is less well known that when light falls on a small barrier, a diffraction pattern is also produced. You can use this fact to measure the size of small biological samples.

In this experiment you will look at samples of your partner's and your own hair. Hair consists of hardened dead cells surrounded by a double sheath. Depending on the rates of formation of the core and the sheath, the hair will be either round, oval or almost flat. These microscopic differences are reflected in what we perceive to be the texture of the hair - round, oval and flat hairs produce straight, wavy and very curly "heads of hair".

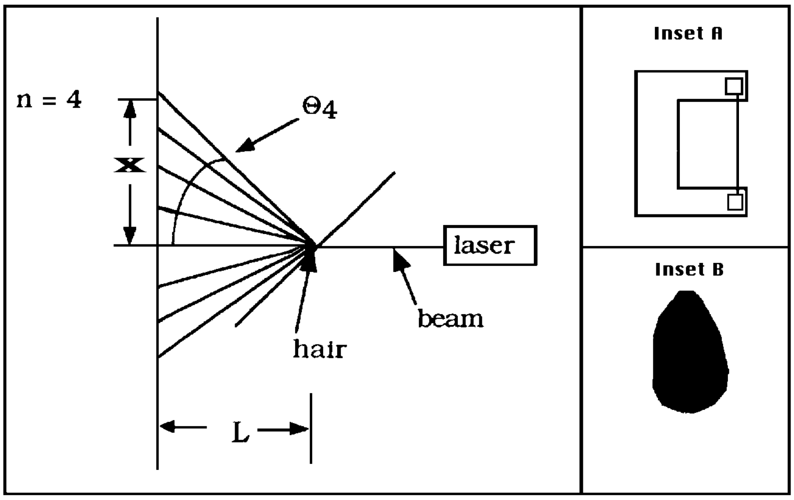
When producing a diffraction pattern with a hair, if you rotate the hair in the beam the diffraction pattern will change, with the diffraction minima moving closer together and then further away as the beam first illuminates first larger then smaller diameters of the hair.

Materials

Cardboard, tape, ring stand and clamp, low powered laser, meter stick, white paper for a screen.

Procedure

1. Mount the single hair to be tested as shown in *Inset A*. Mount the cardboard in front of the laser beam using the ring stand and clamp so that the beam is split by the vertically mounted hair. Position the paper so the beam shining through the hair is displayed on the paper screen. The best results will be found in a darkened room and if the hair is between 1 and 2 meters from the screen.



2. Sketch the pattern observed on the screen. Label the bright regions and the dark regions on the screen.

3. The longest bright region is called the *central maximum* and represents constructive interference as the light is diffracted (bent) around the right and left side of the hair. The dark regions represent locations that are experiencing destructive interference from the light that is diffracting around the right and left sides of the hair.

3. Carefully measure the distance **X** between the centers of the dark region on either side of the central maximum. Also measure the perpendicular distance **L** from the hair to the screen. Adjust the screen distance so that both measurements contain three significant figures!

You **X** = __________________ **L** =

Partner **X** = __________________ **L** =

4. Careful analysis of the constructive and destructive interference patterns would show that width **W** of the human hair can be calculated using the following formulas:

$$W = \frac{(2L)(\text{Wavelength of the laser})}{X}$$

The wavelength of a Helium-Neon laser is 633 nm or 633 x 10^{-9} m.

Calculate **W** in meters and nanometers:

You **W** = _____________ m or _____________ nm

Partner **W** = _____________ m or _____________ nm

5. Repeat steps 1 - 4 with your partner's hair.

Analysis

1. Does a fine hair or a coarse hair result in a greater difference between the regions of the diffraction pattern?

2. How will doubling the width **W** of a hair affect the distances between the regions of the diffraction pattern **X** ?

3. Interference is possible only when one wave source interacts with a second source. How is it possible to observe interference patterns if only one laser is used?

4. How precise would these measurements using interference be for the thickness of a hair compared to using a small ruler and a magnifying glass or using a micrometer? Why?

5. Differentiate between *interference* and *diffraction* by giving a common example of each as well as the standard definition.

6. Why is laser light used in this activity?