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AN INQUIRY BASED LABORATORY
TO TEACH UNITS ON LIGHT AND WAVES/SOUND
IN THE HIGH SCHOOL SCIENCE CLASSROOM

presented by

Deborah Marie Coyne

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AN INQURY BASED LABORATORY APPROACH TO TEACH UNITS ON LIGHT AND WAVES/SOUND IN THE HIGH SCHOOL SCIENCE CLASSROOM

By

Deborah Marie Coyne

A THESIS

Submitted to
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ABSTRACT

AN INQURY-BASED LABORATORY APPROACH TO TEACH UNITS ON LIGHT AND WAVES/SOUND IN THE HIGH SCHOOL SCIENCE CLASSROOM

By

Deborah M. Coyne

The purpose of the research project was to develop laboratory exercises and manuals for Light and Waves/Sound. An inquiry-based laboratory was the setting for teaching these manuals. The goals of this project were 1.) To write lab manuals for light, waves and sound that would cover the MEGOSE objectives. 2.) To write manuals so that students could understand and successfully follow the directions with little explanation from the teacher. 3.) To use an inquiry-based laboratory to improve students knowledge and retention on the topics of light, waves and sound, thus improving their test scores not only in my class but on the MEAP. Overall this project was successful. The students were able to do the lab activities successfully and improved their test scores in physical science. I will have to wait to see if there is improvement on the MEAP scores.

ACKNOWLEDGEMENTS

I would like to take this opportunity to say a special thank you to my husband for his love and support throughout the course of my graduate studies. I would like to thank my family helping out with our children, enabling me to successfully complete my master's thesis. I greatly appreciate all you have done and I could not have done it without you.

Thank you to the people at the Division of Science and Mathematics Education for all the work you have done in providing a masters program that challenges teachers to look at their teaching and continually find ways to improve upon it. I appreciate what you have done for me and I sure my students do as well.

Finally, thank you to the Towsley Foundation for their financial support.

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INTRODUCTION

I. Rationale for Study

I teach tenth grade Physical Science in a new Physical Science Technology Lab. My class has twelve laboratory stations where the students work in pairs on a variety of activities, designed to help them learn the basic concepts and laws of physics. I chose to write the material for the stations on Light and Waves/Sound. There are three primary reasons I chose to write these units.

The first reason is simple: my school purchased a technology laboratory setup which included all the equipment and manuals to teach most of the physics objectives to meet the Michigan Essential Goals and Objectives for Science Education (MEGOSE) except the topics of light, waves, and sound. A fellow teacher and I wrote the manuals for Light and Waves/Sound to go along with the manuals purchased for this class. We had very little experience in writing directions that were clear and explicit enough for students to follow with no or very little help from their teacher. This leads to the second reason I chose this project. When we first wrote the units our instructions were not detailed enough and we had to either stand over the students guiding them through each activity or let the students figure them out on their own. Often students got frustrated and did not do a good job on the activities. It was my goal to re-write lab exercises for Light and Waves/Sound so that the students could successfully complete the laboratory exercises with little help from the teacher. The final and probably most important reason for choosing this project was to show the effect of hands-on activities, discovery learning, and cooperative learning techniques on the students ability to meet the objectives of the unit and retain the information they learned. It is expected that not only will the test scores in my class improve but also the scores on the science portion of the Michigan Education Assessment Program (MEAP) test will improve. With the new course set-up and the new exercises, I expected to see improvement in the open-ended portion of the test (which has been below average in years past) with the use of these learning techniques. Our previous physical science curriculum consisted of a student manual composed of worksheets and labs for the topics we needed to teach. The information was included but it was spoon-fed to the students. They did labs but did not do anything with the information beyond writing a lab report. Our current curriculum, documented in this paper, encourages the students to take responsibility for their learning and an active role in the learning process.

The goals of this project were 1.) to write lab manuals for light, waves, and sound that would cover the MEGOSE objectives. 2.) to write manuals so that students could understand and successfully follow the directions with little explanation from the teacher. 3.) to use an inquiry-based laboratory to improve students knowledge and retention on the topics of light, waves and sound, thus improving their test scores not only in my class but on the MEAP.

II. Comparison of Old and New Approaches

I am comparing two things: the new lab manuals to the previous ones; and the structure of the new science curriculum to the old science curriculum. The approach to writing both manuals was the same: to write clear directions and have activities that would be interesting and relevant to the students and still meet the MEGOSE objectives. As far as the curriculum goes, the two approaches were quite different. The old physical science class was structured around a workbook compiled by one of the former physical science teachers. It consisted of two to three worksheets, two labs and a writing assignment for each unit. The material in the workbooks was not bad; the way we were teaching it needed improvement. When doing a worksheet, I would do a few examples with the class, let them finish it on their own and then we would go over it in class the next day. They did not have to figure anything out for themselves. I would go over the lab directions step by step and guide them through it once they started. I wanted to make sure they got the "right answer". There was no opportunity for self-discovery because I told them everything they needed to know. There was little opportunity for them to learn by making mistakes because I was right there trying to prevent mistakes. The structure of the new physical science class is totally different. The students work with a partner and as a team they rotate through twelve different lab stations. They have ten days to complete the work at each lab station, including completing all the activities and taking a Mid Test and a Post Test. It can be frustrating for the teacher because you have twelve groups each doing something different and you have to make sure everyone is moving along and getting things done on time. Some students do not like the class at first because they have to read the directions and figure things out on their own. They would rather have the teacher telling them what to do. Although the students may find this class more difficult, studies by Hall and McCurdy (1990) indicate that when students use an inquiry-oriented style laboratory they scored higher in content achievement. The format also served as a primary vehicle in promoting conceptual understanding and formal reasoning skills (Lloyd and Contreras, 1987).

There are several studies that show that cooperative learning benefits students academically and socially. Inquiry-based programs enhance student performance, particularly as it relates to laboratory skills and skills of graphing and interpreting data (Mattheis & Nakayama, 1988). Cooperation on learning tasks resulted in students' positive attitudes toward the subject matter and instructional tasks (Johnson, 1984; Haury 1993). Johnson and Johnson (1987) also state that the primary responsibilities of education are learning and socialization, both of which are social processes. Cooperative learning prepares students for today's society. It promotes active learning-students learn more when they talk and work together than when they listen passively. It motivates, leads to academic gains, fosters respect for diversity and advances language skills (Mergendollar and Packer, 1989; Bredderman, 1982). If one looked at these studies, you would think; "great, cooperative learning is the way to go." I do agree, but things do not always go smoothly. Students of this age may be best friends one day and not speaking to each other the next. There are also disagreements about how certain activities should be done or whether one or the other is doing more work. I encourage the students to work their problems out without my intervening. Although it can get tense at times there are benefits. Sharan and Sharan (1987) state that it builds cooperative skills, such as communication, interaction, cooperative planning, sharing of ideas, decision making, listening, taking turns, and exchanging and synthesizing ideas. The students may not always see it or want to admit it, but they are learning life long skills. In a discussion of effective teaching and learning of science, mathematics and technology, Rutherford and Ahlgren (1990) state:

> "The collaborative nature of scientific and technological work should be strongly reinforced by frequent group activity in the classroom. Scientists and engineers work mostly in groups and less often as isolated investigators. Similarly, students should gain experience sharing responsibility for learning with each other. In the process of coming to common understandings, students in a group must frequently inform each other about procedures and meanings, argue over findings, and assess how the task is progressing. In the context of team responsibility, feedback and communication become more realistic and of a character very different from the usual individualistic textbook-homework-recitation approach."

The students must do the things that Rutherford and Ahlgren wrote about in order to succeed in our new physical science class with this new curriculum. I saw students working together, arguing, sharing ideas and planning what they want to accomplish on a given day. I did not see this under the old science curriculum. In the studies looked at by Lazarowitz, Hertz, Baird, and Bowlden (1988), it was found that when using the cooperative approach in teaching science at the secondary level, students' academic achievement and inquiry skills were higher than those in classrooms using a more traditional competitive, lecture-demonstration approach. This is what we want to achieve and we are hoping it will show in our MEAP scores.

As sophomores, students can choose either physical science or chemistry. The majority of college bound students choose chemistry, so I do not get the top students in physical science. I have several students who are either academically challenged or disruptive. Although this curriculum does not alleviate these problems, I do think it is better situation than in a lecture style classroom. Mechling and Oliver (1983) state:

> "Since hands-on science classes do not depend heavily on reading skills, disadvantaged children, usually poor readers, feel on a more equal footing with their classmates. They can and do succeed, often at the amazement of the teacher."

I said earlier the students needed to read to perform the activities but I did make accommodations for those who were not good readers. When I wrote the lab exercises I included several graphics and diagrams to aid in understanding of the directions. I also included several information cards with additional diagrams and explanations on the key topics, which were not part of the previous manuals. This course was challenging for poor readers, but they were much better off than in a textbook-structured class. This hands-on science curriculum also curbed problems with students who tend to be disruptive. Shymansky (1978) found that a class of disruptive students participating in hands-on activities spent 90 percent of the time on the task assigned. An article by Spellman (1989) lists guidelines based on the needs of potentially disruptive students and says that with consideration and understanding, you can create a classroom environment where every child, disruptive or not, enjoys learning science. It is our job to teach all students and our new curriculum helped me do that.

The lab material is not going to do it all; I have to be on my toes monitoring and making sure students are working together. There are pitfalls to this type of teaching. Blosser (1992) warns that it is not cooperative learning if there is no interdependence. Some students want to work on their own and just occasionally check answers with other students. There is also the problem of a student letting their partner do most of the work and then copying. Close monitoring by the teacher is necessary; there is no time for paper checking during this class. Although there are a few disadvantages to this type of teaching style, they are far out weighed by the advantages and I would not want to go back to our old curriculum.

III. Demographics

I teach in a rural district about 25 miles from a major city. There are approximately 750 students in the high school with over 95 percent of that population being Caucasian. I teach two periods of Physical Science & Technology for fifty-five minutes each. There are twelve lab stations with two students per station so the maximum number of students in a class is twenty-four. This year I had 21 and 16 students in my classes, all in tenth grade with the exception of 4 eleventh graders. I had three Hispanic students, the rest are Caucasian. Five of my students were receiving services from the special education department. The students in my class were the students who either chose not to or were recommended not to take Chemistry as a sophomore. Last year I had three classes with 23, 19 and 18 students, all Caucasian and two receiving services from the special education department.

IV. Scientific Background

The two units I wrote, Light and Waves/Sound, are closely related. In each unit, I mention where the students will see this material again in the other unit. Therefore the scientific backgrounds of both units are discussed together.

A wave is a disturbance that transfers energy from place to place. Gases, Liquids and Solids all act as media through which waves travel. Water waves and sound waves require media whereas electromagnetic waves do not. Waves are classified as one of two types, transverse or longitudinal. Transverse waves move at right angles to the direction they are traveling. Longitudinal waves move the medium in the same direction they are traveling. Light is a transverse wave and does not require a medium to travel. Sound is a longitudinal wave. Although they are different types, sound and light waves have some of the same properties, such as amplitude, wavelength, frequency and speed. The formula, Speed = Wavelength x Frequency, can be applied to both types of waves. Both waves follow the law of reflection; the angle of incidence is equal to the angle of reflection. Even though there are many aspects in which sound and light waves behave the same, we also need to look at them individually.

When white light is refracted it can be separated into the color spectrum, red, orange yellow, green, blue, indigo and violet. Violet has the shortest wavelength, 400 nm, and highest frequency, 7.5×10^{14}Hz. You also need to look at where light fits into the Electromagnetic Spectrum, which ranges from radio waves to gamma rays. Visible light is toward the middle between infrared and ultraviolet rays. Electromagnetic waves are electric and magnetic fields that vibrate perpendicular to each other. Together they form an electromagnetic wave that moves through space at the speed of light.

Sound waves require a medium to travel and can easily be altered by the environment they are in. One way to study this is to look at the wave pattern of the same musical note produced by different instruments. Some instruments produce sound with vibrating strings and others with the vibration of air in a chamber. Other variables include the length of the string, how tight it is, the diameter of the chamber or how long it is. When you consider all these factors you can see how easy it is to get very different wave patterns for the same note. Another factor that influences sound waves is movement, either of the object producing the sound or the person receiving it. This is called Doppler effect. The frequency of the waves increases as the object moves toward you and the frequency decreases as the object moves away. When you factor in the effect of the environment on sound waves it makes studying them more difficult.

IMPLEMENTATION OF UNIT

I. Overview

I worked on two related units: Light and Waves/Sound. Each unit consisted of several lab activities using standard lab equipment, computer and sensor equipment and Internet web sites. I also developed a student record book keyed to the directions for each unit. In the record book, students must complete drawings and answer additional questions about the topics studied in each activity. The units also included several pages of information sheets for the students as reference. In the margin of the lab manual I included a record icon so the students would know when they needed to complete something in their student record book and an info icon to let students know there was additional explanation on the topic in the information cards in the back of the lab manual. The information for the info cards can be founding the following textbooks: Science Plus Technology and Society, Holt, Rinehart and Winston; Science Explorer, Prentice Hall; and Conceptual Physical Science, Hewitt. The outline below shows the activities and the principle objectives covered in each unit. Each Roman numeral corresponds to an activity; topics addressed as well as additional activities are listed below.

II. Outline

LIGHT

I. Electromagnetic Spectrum
   a. Properties of electromagnetic waves
   b. Properties of transverse waves in general

II. Reflection: Plane Mirror
   a. Use Light box and optics kit to study plane mirror reflection
   b. Use demo from MSU Lecture on Line to try several incident angles
   c. Specular vs. Diffuse reflection

III. Reflection: Curved Mirrors
   a. Concave mirrors
   b. Concave mirror images
   c. Convex mirrors

IV. Refraction
   a. Rectangular lenses

i. Incident and refracted angles
ii. Index of refraction
b. Convex lenses
i. Use light box and optics kit
ii. Use a demo from MSU Lecture on Line
c. Concave lenses

V. The Eye: How do we see?
a. Eye video
b. Use the Eye Model
i. Nearsightedness and how to correct it
ii. Farsightedness and how to correct it

VI. Rainbows: The Refraction and Reflection of Light

VII. Colors of Light
a. Addition of colors
i. Primary colors of light
ii. Secondary colors of light
iii. Complementary colors
b. Subtraction of colors

VIII. Polaroid Filters
a. Use the light sensor, DL Plus and Datadisc Pro to collect and graph data
b. Use Applet from MSU Lecture on Line to study the effect of 1,2 or3 Polaroid filters

IX. Inverse Square Law of Light
a. Use the light sensor, DL Plus and Datadisc Pro to collect and graph data
b. Manipulate data to verify the Inverse Square Law

WAVES/SOUND

I. Waves: How do they travel?
a. How waves travel
b. Types of waves
c. Use BYU Physics Applets for a demonstration on longitudinal and transverse waves
d. Use MSU Lecture on Line to find out more about the 2 types of waves

II. Properties of Waves: Longitudinal vs. Transverse
a. Wave diagrams
b. Amplitude
c. Wavelength
d. Frequency
e. Speed
f. More on longitudinal waves

III. Reflection
a. Echoes
b. Circular Pulse
c. Plane Pulse
d. Curved Barriers

IV. Diffraction
V. Refraction
VI. Interference of Sound Waves
   a. Constructive and destructive interference
   b. Use Applet from MSU Lecture on Line
VII. Wave Analysis
   a. Relation of Frequency to Pitch
   b. Relation of Amplitude to Loudness
   c. Investigate waveforms from a variety of sources such as tuning forks, human voice and instruments
VIII. Doppler Effect
   a. Use a demo from MSU Lecture on Line
   b. Use a transmitter, receiver, reflector and amplifier to produce an example of Doppler Effect

III. Audio-Visual Aids

I relied heavily on the use of diagrams in the student manual. Diagrams were used to help the students identify and find equipment, explain directions, aid in the explanation of new concepts and to provide additional information on the topics. The graphics were either scanned in or drawn by myself on the computer. The use of visual aids not only made it easier for me to write the directions for the lab activities but also aided in the students ability to follow and carry out the directions correctly. I had far fewer questions on how to do the labs than in previous years.

IV. New Teaching Techniques

Computer based lab sensors were used in both the Light and the Waves/Sound units. The previous lab manuals each contained one computer-based lab. In the new manuals I added one computer-based lab to each unit. These labs enable the students, by using light and sound sensors to collect data, to do activities related to topics they otherwise would only read about. The sensors can be linked directly to the computer and a program called Datadisc Pro is used to set the experimental parameters, record and manipulate data, generate graphs and print tables. The computer based lab equipment we use in the physical science class is from Phillip Harris. The math classes and other science classes use the CBLs from Texas Instruments. It is beneficial for students to use both systems and get exposure to both types of lab technology. I personally like the Phillip Harris equipment because you do not need a different program for each sensor as you do with the CBLs and it is more user friendly. When the students were using the Phillip Harris equipment on the four lab activities they had very few, if any, questions on how to use the equipment or the Datadisc Pro program that goes with it. The less time the students spend figuring out the equipment the more time they can put into the labs.

I included demos and applets from MSU Lecture on Line (software by Gerd Kortemeger, Michigan State University) and BYU Physics Applets in both units. The web sites were used for the demonstration of concepts that could not be done in the lab or to provide additional information on several topics. The use of the web sites was a great way to reinforce what they were seeing in their lab activities or reading about in the lab manual.

V. Laboratory Activities: Description and Analysis

Each activity I modified and developed relates to one or more of the MEGOSE objectives for Waves and Vibrations. The relevant MEGOSE objective(s) for each activity is (are):

LIGHT (Appendix B)

Activity 0: Electromagnetic Spectrum

MEGOSE Objective 14) Relate colors to wavelengths of light.

MEGOSE Objective 16) Describe different types of waves and their technological applications.

This was used as a tool to make sure the students knew what electromagnetic waves were and the properties of transverse waves in general. The students had to read the information and use the diagrams in order to answer the questions on their student record sheet. This activity was meant to lay the foundation for the topics that would be covered in the unit.

Activity 1: Reflection: Plane Mirror

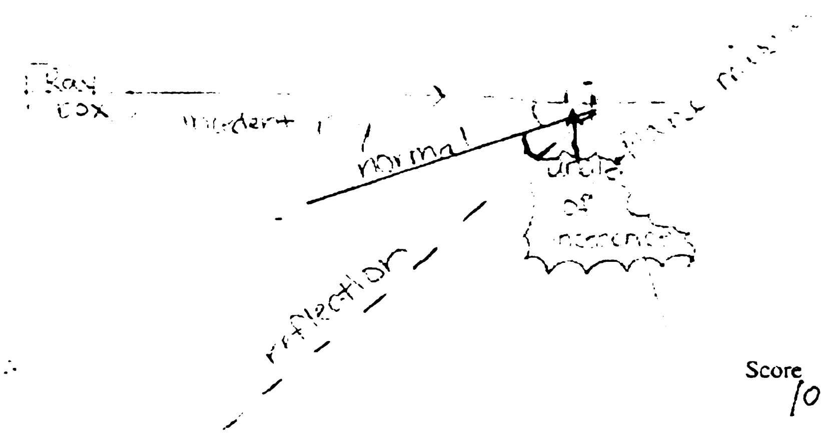
MEGOSE Objective 9) Explain how objects or media reflect, refract, transmit or absorb light.

MEGOSE Objective 11) Explain how waves transmit energy.

The students discovered the relationship between the angle of incidence and the angle of reflection using light rays and mirrors. Most students got the angles to be close in measurement, as shown in this students work below.

Student Record
Activity 1: Plane Reflection

Drawing:



Score	Possible
10	10

Angle of Incidence = ≈21 ° Angle of Reflection = ≈23 °

Score	Possible
4	4

Next they used an applet from MSU Lecture On line to try several different incident angles. There was also a short activity on specular versus diffuse reflection. This is meant to help

students understand why they can see their reflection in some surfaces and they cannot in others.

Activity 2: Curved Mirrors

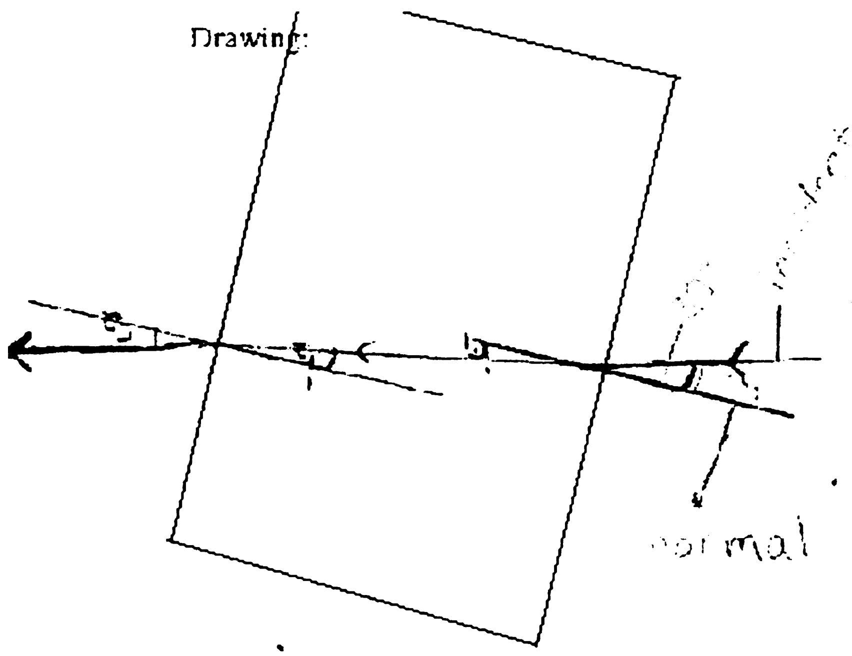
MEGOSE Objective 9) Explain how objects or media reflect, refract, transmit or absorb light.

Students worked with concave and convex mirrors to determine their focal point, focal length and whether they produce a real or virtual image. The students worked with the light box to sketch both incident and reflected rays for both concave and convex mirrors. They also looked in depth at the images produced by a concave mirror, using the mirror, a candle, and an index card to see how the image changes depending on how far the candle is from the mirror. The students were very successful at getting an enlarged image, a smaller image and an image the same size as the actual candle.

Activity 3: Refraction

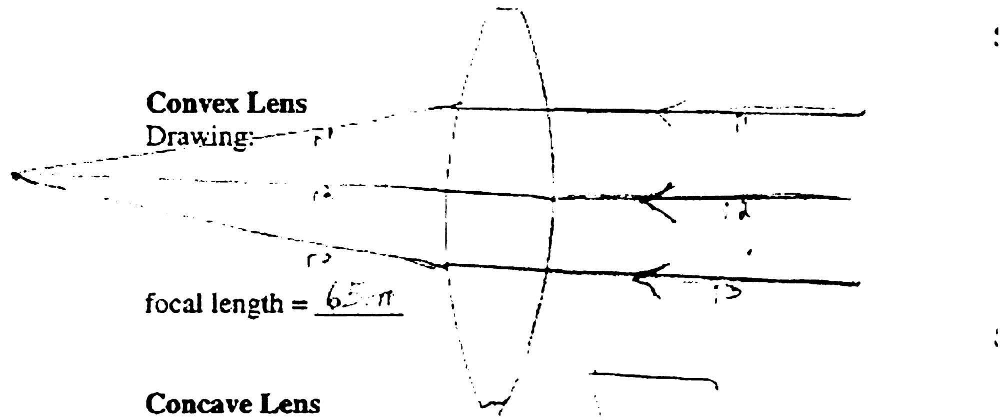
MEGOSE Objective 9) Explain how objects or media reflect, refract, transmit or absorb light.

Students used a rectangular piece of acrylic to show that refraction depends on both light passing from one medium to another and hitting the surface at an angle other than 90°. The students traced the light ray through the rectangular slab used the measurements of the angles to determine the index of refraction going from air to acrylic and from acrylic to air. Most students found this part of the activity difficult. They had trouble with the drawing and determining what angles to measure. Several students did not know what sine was when they were calculating the index of refraction. I did help students calculate the index of refraction so they could explain why one value was less than one and the other value was greater than one. However, students not knowing the definition of sine were confused doing this activity. Following is a sample of a student's drawing; the reader can see how it would be difficult to measure all the angles.



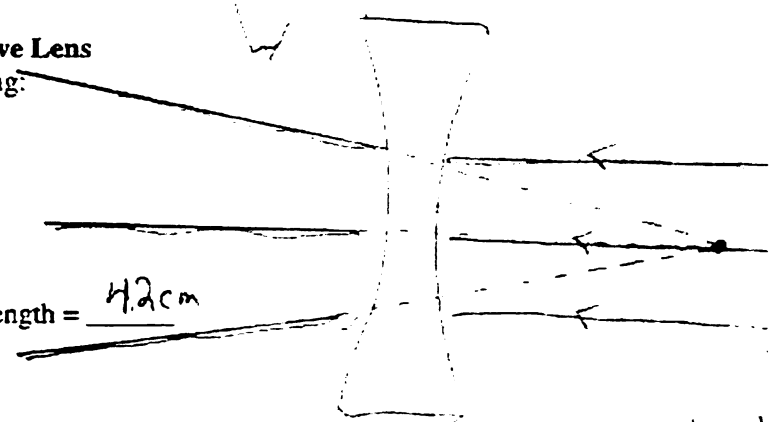
The students did not have trouble using convex and concave lenses, drawing the rays of refraction and determining the focal point. (See below)

Convex Lens
Drawing:



focal length = 6.5 cm

Concave Lens
Drawing:



focal length = 4.2cm

Do you think a concave lens produces *real* or *virtual* images? vitural

Activity 4: The Eye: How do we see?

MEGOSE Objective 9) Explain how objects or media reflect, refract, transmit or absorb light.

MEGOSE Objective 8) Explain how light helps us see.

The students watched a video on the eye, which explained the parts of the eye and their function. Using an eye model helped them see how an image is formed on the retina and what happens to the image when some one is nearsighted or farsighted. They then used the necessary concave or convex lens to correct the problem. This activity used what they learned in activity 3 regarding focal length. Students found this activity interesting because most of them either wear glasses or have someone close to them that does.

Activity 5: Rainbows: The Refraction and Reflection of Light

MEGOSE Objective 9) Explain how objects or media reflect, refract, transmit or absorb light.

MEGOSE Objective14) Relate colors to wavelengths of light.

The students used a prism and the light box to make a rainbow. They studied the diagrams and read carefully through the explanation of how a rainbow is formed before they answered the questions about how, when and where a rainbow is formed in their student record. Most students did very well on the questions in this activity.

Activity 6: Colors of Light

MEGOSE Objective14) Relate colors to wavelengths of light.

The student studied the addition of colors by using the light box and colored filters to show that by mixing the three primary colors of light they get white light. They found which two primary colors of light are added to get each of the secondary colors and found which pairs of colors are complementary colors, combine to form white light. The subtraction of colors is also observed. They lined up filters to see what colors are being subtracted and observed the resulting color. Students had trouble with this activity for a few reasons. First the room was not dark enough. They had to work on the floor under their lab table so it would be dark enough to see the colors. Also they had to be careful not to put the darker colors in the front slot on the light box or it would dominate the two colors being reflected from the sides of the light box. The last problem was they were working with colored filters and after several uses the filters got damaged and the colors produced did not seem to be as clear as in the beginning of the year when the filters were new.

Activity 7: Polaroid Filters

MEGOSE Objective 9) Explain how objects or media reflect, refract,

transmit or absorb light.

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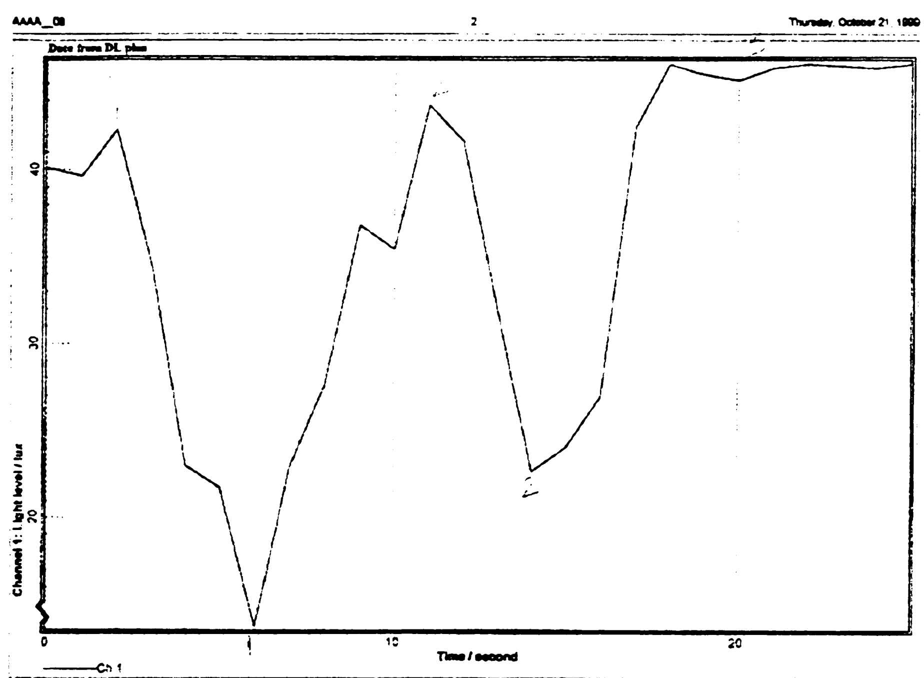
Polaroid filters, the light sensor and the DL Plus were used to determine how much light is allowed through two Polaroid filters as they rotate the top filter and hold the bottom filter in place. The students got a nice graph as a result with the high value being when the filters were lined up at 0° or 180°, letting the most light through and the low value being when one filter was at a 90° angle to the other filter. See below for a representative graph.



The students also used MSU Lecture Online and the Applet on Polarization to further investigate Polaroid filters with one, two or three filters, which gave them the ability to turn each one to any degree they wanted.

Activity 8: Inverse Square Law of Light

MEGOSE Objective 3) Describe light from its light source in terms of its properties.

MEGOSE Objective 8) Explain how light helps us see.

Students used the light sensor and the DL Plus and two different light sources to determine the brightness as they moved away. They used the data they collected to verify the Inverse Square Law. There were a couple of problems the students had to be aware of while doing this lab. First, they had to set up their graph before they start collecting data. The computer program sets the scale on the graph according to the units the light sensor is in. As they moved away from the light source the sensor tells them to change units, which they need to do to get accurate data. However, this changed the units on their graph. As a result their graph starts as a nice downward slope then jumps up and slopes down again. Secondly, the room was not completely dark, so when they were farther away the background light would cause some of the measurements to be higher than they should have been at that distance.

WAVES/SOUND (Appendix E)

Activity 1: Waves: How do they travel?

MEGOSE Objective 2) Explain how sounds are made.

MEGOSE Objective 6) Explain how sound travels through different media.

MEGOSE Objective 11) Explain how waves transmit energy.

This activity explained what a wave is and had the student determine how a wave travels through a medium by using the ripple tank and a piece of styrofoam to determine if the wave is causing water to move across the table or creating a series of vibrations. Students also learn about the two types of waves and how they travel by using the BYU Physics Applets on Transverse and Longitudinal Waves and MSU Lecture Online's Wave Characteristics section 13.14. The students did not have any trouble with this activity.

Activity 2: Properties of Waves: Longitudinal vs. Transverse

MEGOSE Objective 11) Explain how waves transmit energy.

MEGOSE Objective 12) Relate characteristics of sounds that we hear to properties of sound waves.

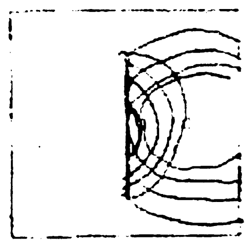
MEGOSE Objective 17) Describe waves in terms of their properties (frequency, amplitude, wavelength, wave velocity)

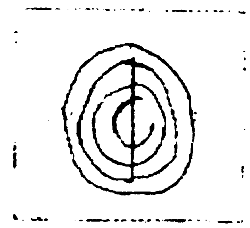
The properties of both longitudinal and transverse waves were explained, including the parts of each wave, amplitude, wavelength, frequency and speed. The students also focused on the compressions, rarefactions, wavelength and amplitude of longitudinal waves using a slinky. There was a string attached to the slinky to help the students see that wave a causes the slinky to vibrate but does not change its position. The students correctly answered the questions that went with this activity.

Activity 3: Reflection

MEGOSE Objective 7) Explain how echoes occur and how they are used.

In this activity the students used the wave table to learn how both circular pulses and plane pulses reflect off curved and straight barriers. The students were told the type of wave to create and the barrier it would hit. Then they drew what the reflected waves would look like. The only problem students had with this activity was that they were looking at the waves they were creating, which were more obvious, instead of the reflected waves so they did not know what to draw in each box. Once I pointed out what they were looking for they did a great job on the drawings as shown below.





Activity 4: Diffraction

MEGOSE Objective 6) Explain how sound travels through different media.

The wave table was used to show how sound waves spread out when they pass through a doorway or by the corner of a wall. The students had no problems with this activity since they were not using any new equipment and were familiar with what was expected in the drawings.

Activity 5: Refraction

MEGOSE Objective 6) Explain how sound travels through different media.

The students used the wave table to show what happens to water waves as they approach the shore. They used the glass refraction plate to observe what happens to the waves that pass over the plate compared with those traveling next to the plate. They also looked at how the angle of the plate affects the wave. Again, the students did not have any trouble with this activity.

Activity 6: Interference of Sound Waves

MEGOSE Objective 18) Describe the behavior of waves when they interact.

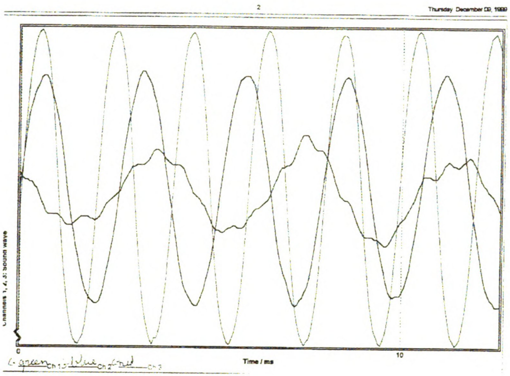
In this activity the students learned about constructive and destructive interference, using the wave table and the applet on interference from MSU Lecture Online to observe interference patterns. The students need to understand that the way in which waves interact is very important in the design of buildings such as concert halls where you are trying to provide the best sound, and to office buildings where you want to minimize the sound. Students did not have any trouble with this activity if they read the corresponding information card.

Activity 7: Wave Analysis

MEGOSE Objective 1) Describe sounds in terms of their properties (pitch, loudness).

MEGOSE Objective 10) Describe the motion of pendulums or vibrating objects (frequency, amplitude).

The students used tuning forks, the sound meter, DL Plus and Datadisc Pro to generate graphs of the wavelength and amplitude of the waves produced by different tuning forks, as well as their voice and other instruments. (See below) The students used the information from their graphs and the information provided to them in their student record to answer several questions about loudness and pitch. The majority of students did well with this activity and understood how loudness relates to amplitude and pitch relates to frequency.



Activity 8: Doppler effect

MEGOSE Objective 19) Relate changes in detected frequency of a source to the motion of the source and/or the detector.

This activity started with a series of pictures to show how the frequency of the sound waves are affected as a plane moves. The students also watched the Doppler effect demo of a passing police car on MSU Lecture Online. Then the students created their own Doppler effect using a transmitter, receiver, reflector and an audio amplifier. The frequency of the beats produced by the transmitter is changed when they hit the moving reflector. As the student moved the reflector toward the transmitter the frequency increased and has a higher perceived pitch. When the reflector is moved away the frequency decreases and has a lower perceived pitch. The students drew and explained Doppler effect using a police car siren. The students did great with the drawing and they explained that the frequency would increase as it was approaching and decrease after it passed. However, several of them said that the increase in frequency would make the siren louder and it would be quieter after it passed. After hearing the Doppler effect, they were interpreting the higher pitch as being louder even after they had done so well on the previous activity.

EVALUATION

I. Pre and Post Tests

I used Pre and Post Tests (Appendix A) to evaluate how much my students learned as a result of the revised Light and Waves/Sound units. I concentrated on specific objectives for my Pre and Post Tests; there were a few questions on the Post Test that were not on the Pre Test. Therefore, I looked for improvement on specific questions, not at the average of the test scores. I also looked at those same questions on the semester exam to measure retention.

Table 1. LIGHT Pre and Post Test Data

N = 20

Objective	Points Possible	Pre Test Average Score	Post Test Average Score	Exam Average Score
Electromagnetic Spectrum	1	0.4	0.6	0.8
Transverse Wave Diagram	2	1.5	1.8	1.9
Reflection	3	1.6	2.0	2.3
Refraction	2	0.1	0.7	1.6
Primary Colors of Light	3	2.2	2.4	2.6
White Light	1	0.1	0.3	0.6
Rainbows	3	0.3	1.3	1.9
Polaroid Filters	3	0.1	1.6	1.4
Brightness	2	0.4	1.0	1.5

The table shows that scores improved on each objective. The largest increase was on the question having to do with Polaroid Filters. This may be misleading since most students left it blank on the Pre Test and at least tried to answer it on the Post Test. The average for this question went from a 0.1 out of 3 to a 1.6 out of 3, which was better but not great. The

results for refraction did not improve much from Pre Test to Post Test because the students treated the lenses as if they were mirrors. They were drawing how the rays would be reflected off a curved mirror instead of how they were refracted through a concave or convex lens. If I could tell that is what they did, I asked them if they realized that the question dealt with lenses not mirrors and what should happen to the light rays. In this circumstance most of them could tell me the correct answer. The score on this question was considerably better on the Exam. I believe that was because the students were more careful and knew that both lenses and mirrors would be on the Exam. The scores also went up in all the other objectives, except one, on the final Exam, which I expected. When the students finished the first half of the unit they took a Mid Test and when they finished the second half they took a Post Test. I did not review with them; they studied on their own and told me when they were ready to take the test. They had ten days to complete the unit; the tests must be taken within that time. Other than that, they were on their own. Before the Exam we reviewed the material, they knew what was going to be on the Exam and the scores improved. Even though I expected the scores to improve compared to the Pre and Post Test, I was pleased with how much better they were, because my top students did not have to take the Exam. At our school, if a student is passing and has two or less excused absences they do not have to take the Exam. Those students taking the Exam were not the best students in the class, yet they did well.

Table 2. WAVES/SOUND Pre and Post Test Data

N = 20

Objective	Points Possible	Pre Test Average Score	Post Test Average Score	Exam Average Score
Longitudinal Wave	3	2.15	2.25	1.67
Frequency/Wavelength	2	1.5	1.8	2
Loudness/Pitch	6	4.6	5.35	6
Doppler Effect	6	2.15	3.7	3.83
Reflect/Refract/Diffraction	3	1.75	2.4	1.83

The scores on the sound unit improved for each objective when comparing the Pre Test to the Post Test, but the scores did go down in two objectives on the Exam. The first was the question on longitudinal waves, which was a diagram where the students had to label the wavelength, compression and rarefaction. On the Exam, a few students switched the ideas of compression and rarefaction, bringing the average down considerably, since there were not very many taking the Exam. The second question with a lower score on the Exam was a matching question on the definitions of reflection, refraction and diffraction. A few students switched diffraction and refraction, which can be tricky. Overall I was pleased with how they did on the Post Test and the Exam.

II. New Teaching Strategies

I was looking for improvement between this year's Pre and Post Tests and for improvement in the scores on the tests over the previous two years scores. By comparing the 1999-2000 scores with the 1997-1998 scores, I can get an idea of the impact of the new lab structure, which is primarily student directed, versus the old curriculum which was primarily a teacher directed, lecture situation. I also wanted to see if the new activities and re

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revised directions improved the test scores from the 1998-1999 school year, the transitional year to the new curriculum.

There was not a significant change in the test averages. None of the tests were the same, although they did include a few of the same questions. I know all three tests included drawings of light rays hitting concave and convex mirrors and lenses, questions about the primary colors and a diagram of a transverse wave but the other questions on the test were different. The other thing that needed to be taken into account when I looked at the test scores was that in 1997-1998, when our physical science course was teacher directed, we had a test policy that if a student got a 80% or better on the test they could do an extra credit activity to add up to 20 points to their test score. If the student got below an 80% they had to retake the test. I do not have the test average before the extra credit and the retake but I would suspect it was quite a bit lower. Retests were not given in the 1998-1999 or 1999-2000 physical science classes.

There was also no significant improvement in the average for the Waves/Sound unit. Even though the whole test was not the same, parts of it were. Again, the 1997-1998 class had the opportunity for extra credit or retaking the test, which inflated their average compared to the 1999-2000 school year. I do not have any test data for this unit from the 1998-1999 school year because a fellow teacher wrote this unit the week before school. The directions were so poorly written that there were several activities where I could not follow the directions and questioned the purpose of the activity. Revisions were not made so students skipped that unit until he made them. I do not have any data from last year (1998-1999) for the Waves/Sound unit.

The best way to judge whether the new physical science curriculum is benefiting our students will be to see if the scores on the MEAP test improve. The first group of students to go through this revised class took the MEAP this spring and I do not have the results; I am anxiously awaiting them! I asked a former student how she felt about the science portion of the MEAP, she said she thought she did well and it was one of the easier portions of the test. The 1999-2000 physical science classes, who used the new manuals I wrote, will not take the MEAP until the spring of 2001.

One of my goals was to write clear and explicit directions in order to reduce student frustration and improve the student's performance on the activities. Since the activities were all either changed in some way or new, the best way to compare them is to look at the average score the students received on their student record for each year. Again, I cannot compare the scores for Waves/Sound since I do not have data from last year but I do think it is important to look at how the students did.

Table 3. LIGHT Student Record Averages

STUDENT RECORD	1998-1999	1999-2000
CLASS AVERAGE	76.9%	70.7%

Table 4. WAVES/SOUND Student Record Averages

STUDENT RECORD	1998-1999	1999-2000
CLASS AVERAGE	No Data	78.1%

The average scores on the student records did not improve but went down. This concerned me because I had a sense when I was grading the papers that most students knew what they were doing and were doing a good job conveying that in their student record. I looked at the scores more closely. There was a difference between the two years in that in 1999-2000, four students get zeros on their student record because they were absent and never came in to make it up and in 1998-1999 I only had one student in that situation. I calculated the averages without those scores and the average for the year 1999-2000 went up to 77.2% and the average for 1998-1999 went up to 77.9%. The average for the two years did not show the change that I had expected it would. However, I was spending less time explaining each activity, which I am sure caused the scores to be lower. The previous year I was helping with the activities and helping the students get the correct answers but they were not making discoveries on their own. This year the students were doing the work on their own and making a few more mistakes on their student record. I believe they learned more from the mistakes and, as research has shown, should remember the material better than if I was guiding them through each step.

III. Anecdotes

I could not do interviews or surveys and have the students compare the old versus the new because they were only exposed to the new units. One student, who was repeating physical science, told me that he liked the old way (lecture style) better because it was easier. He did not like the way it is now because you have to think too much. I also had a student who was repeating the class this year, so I asked him what he thought about the new manuals. He said the Waves/Sound unit was better because he skipped that unit last year because of the previously explained problems with it. He did not like the Light unit either year because he felt it was too hard. He said that the directions were easier to follow this year. He received an 80% for his work on the unit this year. I cannot compare it with what he did last year because he dropped out before the end of the semester and was deleted from my class list on the computer.

I talked with the other teacher who has been teaching this class and he felt the units went much smoother and he had to spend little time explaining the activities. In the previous year we both felt we had to explain almost every activity. There are still a few things I would like to improve; however, both my colleague and I feel that I achieved my goal of writing the manuals so that the students were able to follow the directions and successfully complete the activities with little help from the teacher.

DISCUSSION AND CONCLUSION

I. Effective Aspects of the Units

The activities that were most effective were the ones where students had to study a particular objective three different ways. For example, Activity 1 Reflection: Plane Mirror in the Light unit had the students using the information cards which helped them understand the new vocabulary, they did the activity using plane mirrors and then they used an Internet applet as a follow up activity. For each objective they could gain information from the lab manual, particularly the information cards, and from doing the activity. The students were most successful when I included another way for them to get the information, such as using the demos and applets from the Internet sites. The information reinforced what they were doing in the lab activity and helped them to verify their conclusions.

The student directed-cooperative learning situation in the physical science class was new to the students and to myself. Several students struggled at the beginning of the year and I did as well. They had to determine how they were going to work with their partner; some groups figured this out much faster than others. They also had to get used to solving problems without direct guidance from their teacher. This is the biggest challenge for the students and the teacher. It was difficult for me to sit back and let the students struggle to solve problems. I wanted to jump in and help them; sometimes I did and probably should not have. I did not have any training before I taught this class so I was learning along with the students but I have become a better teacher as a result. I have come to be a facilitator in this class. The students are going to ask questions but the teacher needs to be able to prompt the students and ask them questions. The students need to be able to find the solutions on their own. The teacher has to put the responsibility on the student, yet at the same time show they care and are there to help the students rather than tell them what to do. Once the students understand how the class works, you go from answering how to you do this type questions to I tried this and I am not sure why its not working type questions. It never gets easy, you still have to monitor twelve different groups but it does get better.

The effectiveness of this type of learning environment is hard to measure. I did the Pre and Post Tests to show how well the students met certain objectives. The goal of improving the students' problem solving skills is not so easy to evaluate. I observed them throughout the year and I could see drastic improvement in not only their approach to problems but in their ability to solve them as well. Although I could not measure this, I asked the students a more open-ended question on the second semester final to determine what they felt was important from the two units. The students were asked to explain three concepts they learned at the station. Below are some responses for both the Light and Waves/Sound unit.

Light:
"A convex mirror forms a virtual image because the focal point is behind the mirror."

"Angle of incidence equals angle of reflection."

"Electromagnetic waves are transverse waves with both electrical and magnetic properties."

"Diffuse- when you look into paper your reflection goes everywhere so you can't see yourself."

"I learned that in the northern hemisphere we don't see a rainbow in the south because the sun has to be behind you and the raindrops in front of you."

"Red, Green and Blue are the primary colors of light."

Waves/Sound:
"Crests and trough affect the amplitude which in turn determines the loudness of the sound."

"Some animals use sound reflection to communicate or locate food."

"The higher pitch the sound has the higher frequency the wave has."

"If you increase the wavelength or frequency of a wave you increase the speed."

"Sound is traveling through the air because the particles are being pushed together and apart."

"Light waves are transverse waves and sound waves are longitude waves."

Their wording may not be perfect but they understood the ideas. These responses gave me a better indication of what the students were going to remember.

II. Aspects that need improvement

The activity that definitely needs improving is Activity 3 in the Light unit, where the students had to trace the light ray through a rectangular piece of acrylic and measure the angles of incidence and refraction. I plan to make a diagram for each step of the process and make them bigger so it is easier to identify the normal versus the incidence ray. I would also have them use a larger angle of incidence so their drawings would not be so crowded and the angles would be easier to identify and measure. I still would not go into the mathematics of sine but I would explain how to plug the formula for index of refraction into their calculator. If these changes do not help, I will look for another way to show refraction and what the index of refraction means.

Activity 8 on the Inverse Square Law also needs some changes. The students had to change the units on the light sensor as they got farther away from the source to get accurate measurements. In doing so, they mess up the graph generated by the computer. I will have them change the units on the light sensor as it indicates, collect their data and then either graph it themselves or type the data into the computer themselves and then have the computer graph it when they are done.

The last activity I want to improve is Activity 8 the Doppler effect, from the sound unit. I want to find a way to stress to the students that the change in frequency is causing the pitch to change not the loudness. I am going to try to develop an activity using the sound sensor so the students can print a graph of the waves and see that a change in frequency does not mean there is a change in amplitude and relate this information to Activity 7.

III. Conclusions

Overall I was pleased with the student's ability to follow the lab manuals with very little assistance and with their performance on the student records. I am going to make the changes as stated above and continue to monitor the average scores to help identify changes I may need to make in the future. As for the effectiveness of the program, I will wait until the MEAP scores to arrive for concrete evidence. As I said in the introduction, I expect to see more improvement in the open-ended portion of this test but I also would expect improvement in the multiple-choice section. I will definitely apply what I learned from my thesis project to my other classes. This summer (2000) I am working on the curriculum for our new astronomy class and I am trying to incorporate as many labs, group explorations and activities as possible. I have seen the benefits in my physical science class and want to have the same learning atmosphere in my astronomy class.

BIBLIOGRAPHY

Blosser, Patricia E. (1992). Using Cooperative Learning in Science Education. CSMEE Bulletin

Bredderman, Ted (1982). Activity Science-The Evidence Shows It Matters. *Science and Children*, 20, 39-41

Hall, Donald A., & McCurdy, Donald W. (1990). A Comparison of a Biological Sciences Curriculum Study (BSCS) Laboratory and a Traditional Laboratory on Student Achievement at two Private Liberal Arts Colleges. *Journal of Research in Science Teaching*, 27(7), 625-636

Haury, David L. (1993). Teaching Science through Inquiry. *ERIC/CSMEE Digest.*

Johnson, D. W. (1984). Circles of Learning, Cooperation in the Classroom. Alexandria, VA: Association for Supervision and Curriculum Development

Johnson, R. T., & Johnson, D. W. (1987). Cooperative learning and the achievement and socialization crisis in science and mathematics classrooms. *Students and Science Learning*, 67-93

Lazarowitz, R.; Hertz, R. L.; Baird, J. H. & Bowlden, V. (1988). Academic Achievement and On-Task Behavior of High School Biology Students Instructed in a Cooperative Small Investigative Group. *Science Education*, 72(4), 475-487

Lloyd, C. V., & Contreras, N. J. (1987). What research says: Science inside-out. *Science and Children*, 25(2), 30-31

Mattheis, F. E., & Nakayama, G. (1988). Effects of a laboratory-centered inquiry program on laboratory skills, science process skills, and understanding of science knowledge in middle grade students. *ERIC/CSMEE Digest.*

Mechling, Kenneth R., & Oliver, Donna L. (1983). Activities, Not Textbooks: What Research Says about Science Programs. *Principal*, 62(4), 41-43

Mergendollar, J., & Packer, M. J. (1989). Cooperative Learning in the classroom: A knowledge brief on effective teaching.

Rutherford, F. J., & Ahlgren, A. (1990). Science for all Americans. New York: Oxford University Press.

Sharan, Y., & Sharan, S. (1987). Training Teachers for Cooperative Learning. *Educational Leadership*, 45(3), 20-25

Shy

Spe

Shymnasky, J.A. (1978). Activity-centered science. *Science and Children*, 15(6), 38-39

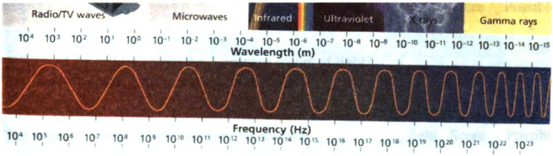
Spellman, Susan O. (1989). Mission Possible: Teaching Hands-on Science to Disruptive Students. *Science and Children*, 26(4), 15

APPENDICES

LIGHT PRE-TEST

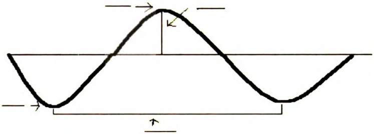
Name ________________

1. Which has a higher frequency X-rays or radio waves? ______________________



Score Possible
1

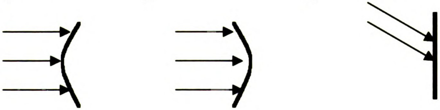
2. Label the parts of the transverse wave below:
   a. crest b. trough c. wavelength d. amplitude



Score Possible
2

3. Complete each of the diagrams below by drawing what happens to the light rays after hitting the mirrors.

a. b. c.



Score Possible
3

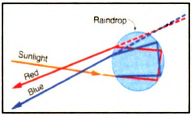
4. Draw how the light rays are refracted when they hit the lenses below.

Score Possible 2

5. Which of the following are the 3 primary colors of light? ____________________
Red, Magenta, Yellow, Green, Blue, Cyan Score Possible 3

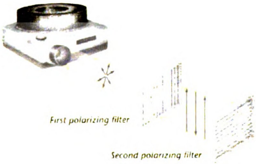
6. The primary colors of light combine to produce ___________light. Score Possible 1

7. Explain how a rainbow is formed.



Score Possible 3

8. Explain how Polaroid filters **work** and what they are **used** for.



Score Possible 3

9. List 2 physical characteristics that affect the brightness of a light source.
1. ______________ 2. ______________ Score Possible 2

LIGHT MID-TEST

Name________________

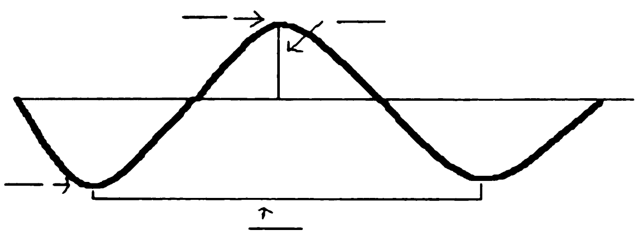
1. Which has a higher frequency, gamma rays or microwaves? ________________

Score Possible
1

2. Electromagnetic waves are transverse waves with both ___________________ and magnetic properties.

Score Possible
1

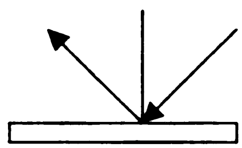
3. Label the parts of the transverse wave below:
   a. crest b. trough c. wavelength d. amplitude



Score Possible
2

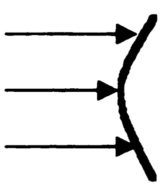
4. Match the name with the correct number for each part of the ray of light hitting a flat mirror diagram.

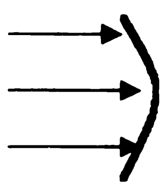
Normal _____
Reflected Ray _____
Incident Ray _____

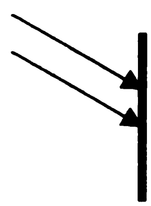


Score Possible
3

5. Complete each of the diagrams below by drawing what happens to the light rays after hitting the mirrors.

a. 

b. 

c. 

Score Possible
3

TOTAL Possible
10

LIGHT POST-TEST

Name ________________

1. Draw how the light rays are refracted when they hit the lenses below.

Score Possible
2

2. When you are looking at something close up, what happens to the shape of the lens in your eye? ________________ Score Possible
1

3. On what part of your eye does the image form? ________ Score Possible
1

4. What type of lens is needed to correct Nearsightedness? ________ Score Possible
1

5. Which of the following are the 3 primary colors of light? ________________
Red, Magenta, Yellow, Green, Blue, Cyan Score Possible
3

6. The primary colors of light combine to produce ________light. Score Possible
1

7. Explain how a rainbow is formed.

Score Possible
3

8. Explain how Polaroid filters **work** and what they are **used** for.

Score Possible
3

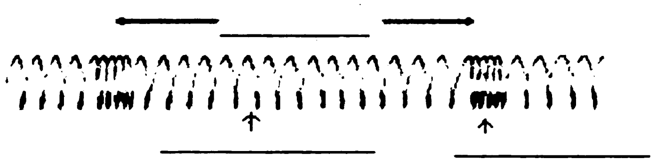
9. List 2 physical characteristics that affect the brightness of a light source.
1. ________ 2. ________ Score Possible
2

WAVES/SOUND PRE-TEST

Name ________________

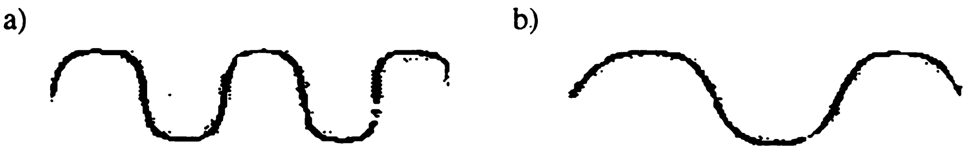
1. Label the parts of the wave below:

   a) rarefaction b) wavelength c) compression



Score Possible
3

Using the wave diagrams below answer questions 2 & 3.

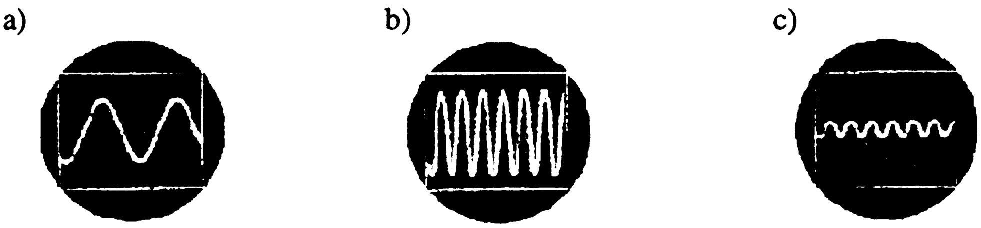


2. Which wave has a higher frequency? ________

3. Which wave has a longer wavelength? _______

Score Possible
2

Using the wave diagrams below answer questions 4 & 5.



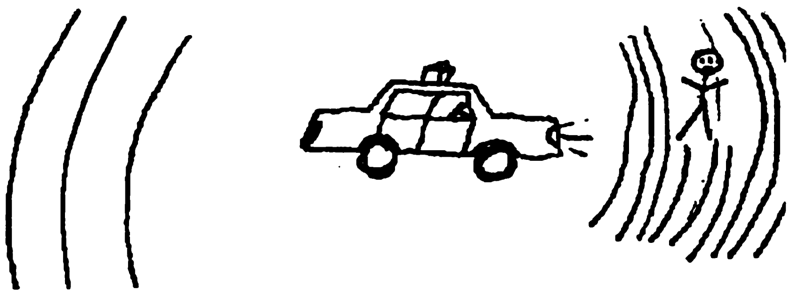
4. Which wave represents a sound that is loud and high pitched? _______

5. Which wave represents a sound that is soft and high pitched? _______

6. Which wave represents a sound that is loud and low-pitched? _______

Score Possible
6

7. Explain the Doppler Effect as it applies to police car passing you with its siren on. (Look at the diagram to help you explain it.)



Score Possible
6

Match the following terms with the correct description.

_____8. Reflection	A. The wave hits a surface and bounces back.
_____9. Refraction	B. The bending of waves around the edge of a barrier.
_____10. Diffraction	C. A change in the medium causes a wave to bend.

Score Possible
3

WAVES MID-TEST

Name____________________

Match the following terms with the correct description.

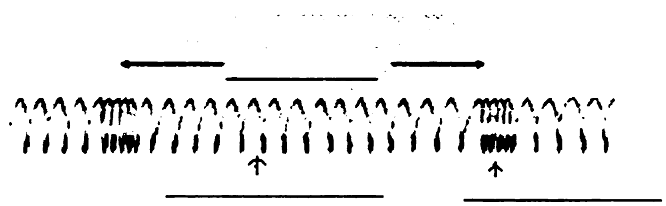
_____1. Reflection	A. A change in the medium causes a wave to bend.
_____2. Refraction	B. The bending of waves around the edge of a barrier.
_____3. Diffraction	C. The wave hits a surface and bounces back

Score Possible
3

4. The 2 types of waves are ____________________and ____________________.

Score Possible
2

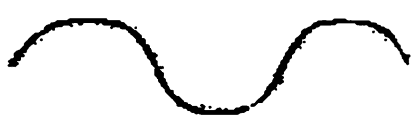
5. Label the parts of the wave below:
   a. rarefaction b. compression c. wavelength



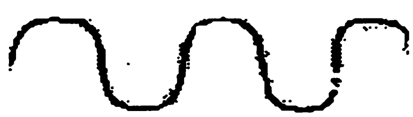
Score Possible
3

Using the wave diagrams below answer questions 6 & 7.

a)



b)



6. Which wave has a higher frequency? ________

7. Which wave has a longer wavelength? _______

Score Possible
2

TOTAL Possible
10

WAVES/SOUND POST-TEST

Name_________________

1. _________________ is the ability of 2 or more waves to add together to form a new wave.

Score Possible
2

2. What do the dark areas represent in the diagram below? _______________

What do the light areas represent in the diagram below? _______________

Score Possible
2

3. When constructive interference occurs is the new sound wave louder or softer than the original sounds? ________________

Score Possible
1

4. When ________________ interference occurs the resulting wave is softer or completely concealed.

Score Possible

1

5. Loudness is determined by the _______________ of the wave.

Score Possible
2

6. Pitch is determined by the ________________ of the wave.

Score Possible
2

7. Draw a sound wave that is loud and high pitched.

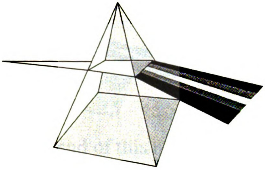
Score	Possible
	3

8. Draw a sound wave that is soft and low pitched.

Score	Possible
	3

9. Explain the Doppler effect as it applies to an airplane passing over you.
(Draw a diagram if it helps you explain it, but you need to explain it.)

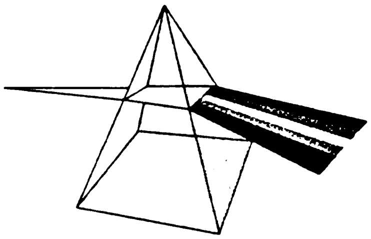
Score	Possible
	6

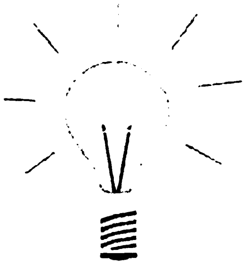


Light

Student Manual

Light Objectives



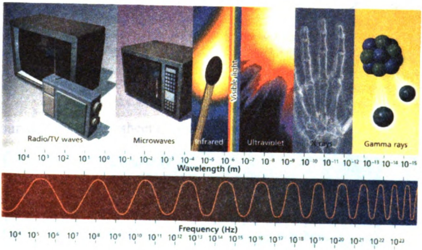


At the end of this unit you should:

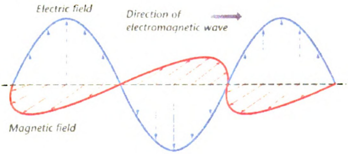
- Know what the electromagnetic spectrum is and how the wavelength and frequency change as you go across the spectrum.
- Know what type of wave an electromagnetic wave is and the speed at which they travel.
- Be able to label the parts of a transverse wave.
- Understand reflection for a plane surface.
- Understand how images are formed for convex and concave mirrors.
- Be able to explain refraction and calculate the index of refraction.
- Understand how images are formed for convex and concave lenses.
- Understand how the eye works and how we see.
- Know the colors of the spectrum.
- Explain how a rainbow is formed.
- Know the primary and secondary colors of light.
- Know what complementary colors are.
- Explain how Polaroid filters work.
- Understand how the Inverse Square Law applies to different light sources and the physical characteristics of the sources, which affect the brightness.

Activity 0

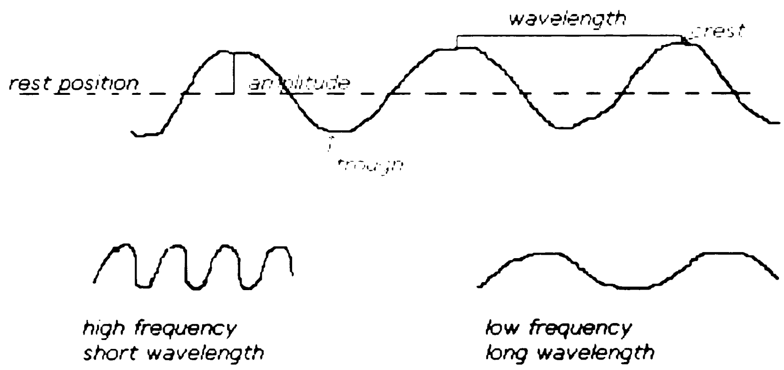
You cannot feel or hear them but as you read this you are surrounded by radio waves, infrared, visible light, UV, and maybe tiny amounts of X-rays and Gamma rays. These waves makeup the electromagnetic spectrum.



Electromagnetic waves are **transverse waves** that have both electrical and magnetic properties.



All electromagnetic waves travel at the same speed, about 300,000,000 meters per second in a vacuum. At this speed, light from the sun travels 150 million kilometers to Earth in ~8 minutes. Nothing can travel faster! When electromagnetic waves travel through a medium such as glass, they travel more slowly. But even at slower speeds, electromagnetic waves travel about a million times faster then sound can travel in air.



RECORD

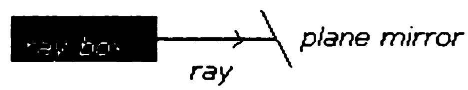
Go to your student record sheet to answer questions.

Reflection: Plane Mirror

Activity 1

For this activity you will need the Light Box and the plane mirror from the optics kit.

Go to your Student Record sheet and in the space marked drawing; project a single ray on your paper. Place the mirror in the light path on an angle. Draw the mirror the ray and a line along the front of the mirror as shown below.

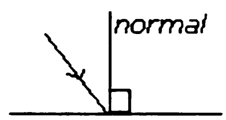


Label this ray as your **incident ray**.
Draw the **reflected ray** with a dotted line and label it.

Draw a line perpendicular to the mirror at the point where the incident and reflected ray meet the mirror and label it as the **normal**.

Draw and arc between the *incident ray* and the *normal* to show an angle. This angle is called the **angle of incidence** or **incidence angle**.

Measure the angle of incidence and record.



Draw an arc between the *reflected ray* and the *normal*. This is called the **angle of reflection**.

Measure the angle of reflection and record.

Now lets try some different incident angles. You do not have to draw them. Get a pass from your teacher and go to the library so you can use the Internet. Go to Mrs. Coyne's web site. (http://hobbes.lite.msu.edu/~Coyne)

Click on **MSU Lecture on Line.**

To login type: Username: **demo**
Password: **demo**
Class: **phy232c**

Click the ∇ next to Welcome.
Click on Ch.9 Mirrors & Lenses.
Click the ∇ next to 9.1 Mirrors & Lenses.
Click on Applet 9.5 Refraction.

Put your mouse on the incident ray and drag. Notice the angle of incidence and angle of reflection.

Pay attention to the angle of refraction also, you will be studying this in Activity 3.

Complete Reflection questions on your student record.

Specular vs. Diffuse Reflection

You have been looking at reflection from a very smooth surface this is called **specular refection.**
Most of the time we see "scattered reflection", the scientific term is **diffuse reflection.**

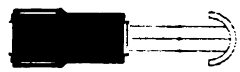
Examine the diagrams below and then answer the questions on your student record.

Activity 2

Concave Mirrors
Place the ray box and either curved mirror from the optical set on the correct page of your record sheet.

Aim a set of parallel rays into the center of the concave side of the mirror.

Draw a line along the mirror and the incident rays as shown below.



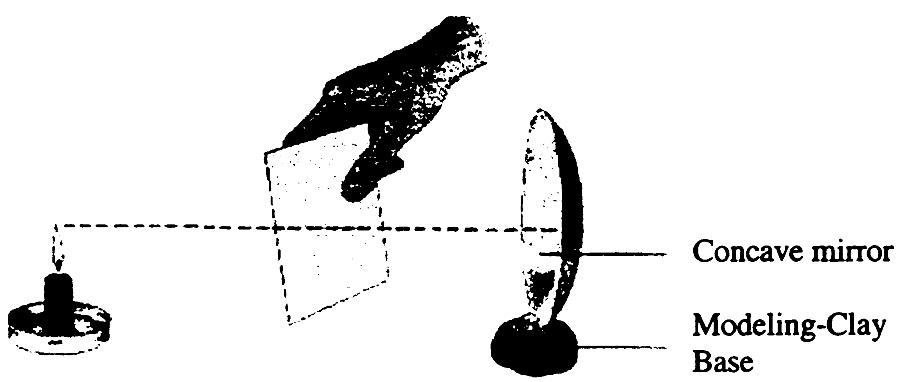
Draw the reflected rays. Make a dot where the reflected rays meet, label this point the **focal point**.

Measure the distance from the focal point to the mirror. This distance is called the **focal length**.

Concave-Mirror Images
For this section you will need the bigger concave mirror, an index card, and a candle (get from your teacher).

Light the candle. Be careful and do not mess around!

Hold the index card between the concave mirror and the candle, as shown below.



Move the mirror slowly back and forth toward the index card. Look for an image on the card. Once you get an image, leave it set up and go to your record sheet.

Continue the experiment until you can construct the 3 diagrams listed below on your record sheet.

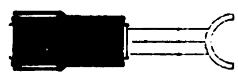
1. Show where the candle, index card and mirror are placed if a very small image is desired.
2. Show the setup that produces an image the same size as the object.
3. Show how the candle, index card and mirror should be arranged to produce and image larger than the object.

Convex Mirrors

Place the ray box on the correct page of your record sheet.

Aim a set of parallel rays into the center of the convex mirror.

Draw a line along the mirror and the incident rays as shown below.



Draw the reflected rays.

Remove the mirror and extend the reflected rays behind the mirror with dotted lines until they meet.

Make a dot where the dotted rays meet, label this point the **focal point**.

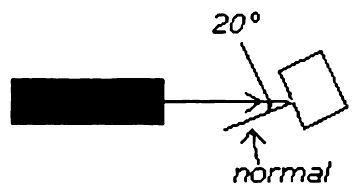
Measure the distance from the focal point to the mirror. Again distance is called the **focal length**.

Activity 3

Place the rectangular slab with the long side perpendicular to a single beam as shown below.

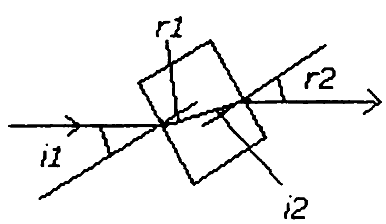
The ray passes from one medium (air) into a second medium (acrylic plastic) and vise versa on the way out. Where the two media meet is called an **interface**.

Go to the drawing space on your record sheet and trace the slab on your paper. Now move the light box so the ray hits the slab at an incidence angle of 20°. Hint: You need to draw the normal first.



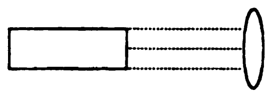
Draw the incident ray and the emergent ray.
Remove the slab and draw the ray path through the slab.

Draw the normal where the ray enters and emerges from the slab as shown below.



Measure the angle of incidence and refraction at both interfaces.
(i1 & r1) (i2 & r2)

Convex Lenses
Select one of the BI-convex lenses.
Trace it on your record sheet.
Aim 3 parallel rays of light at the lens.



Draw the incident and refracted rays.

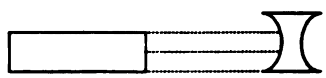
Remove the lens and connect the incident and refracted rays.

Label the focal point and find the focal length.

Go to Mrs. Coyne's Web site. (**http://hobbes.lite.msu.edu/~Coyne**)
Click on MSU Lecture Online.

To Login type: Username: **demo**
Password: **demo**
Class: **phy232c**
Click on Welcome.
Click Ch. 9 Mirrors & Lenses.
Go to 9.19 Principal rays for lenses and click.
Read over the information, then click on **demo**, let it load up and then click the > to play.

Concave Lenses
Trace the BI-concave lens on your record sheet.
Aim 3 parallel rays of light at the lens.



Draw the incident and refracted rays.

Remove the lens and extend the refracted rays back toward the light box.

Note where the lines meet, label this point the focal point and measure the focal length.

The concave lens is a diverging lens and is said to have a negative focal length because the point where the rays appear to come from is between the light and the lens.

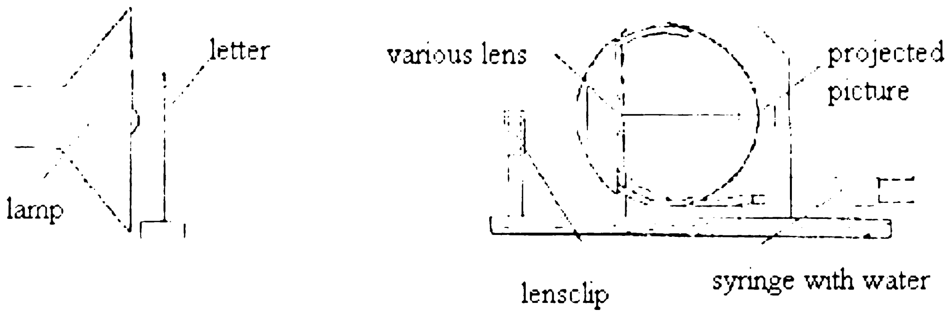
Activity 4

View the Eye video and complete your student record sheet.

RECORD

Eye model

You need to get a lamp and then get the eye model and its accessories from your teacher. Then set it up as shown below.



Now remove the plastic tubing from the lens. Leave the tubing on the syringe.

Get a beaker of distilled water from you teacher.

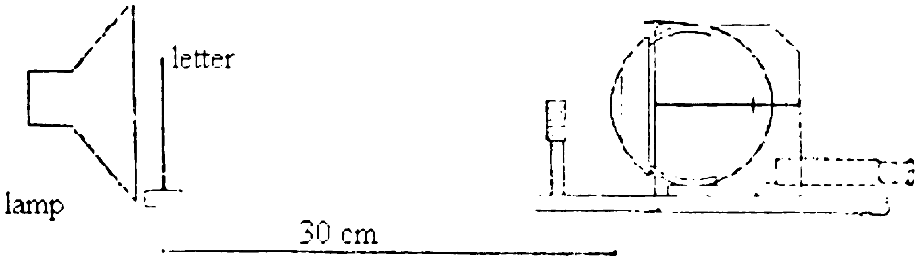
Fill the syringe with water. Remove any air bubbles.

Press the lens as flat as possible to remove the air inside it.

While pressing the lens attach the tubing to back on try not to let any air into the lens.

Nearsightedness

Place the eye model and the plate with the letter 30cm apart as shown below.

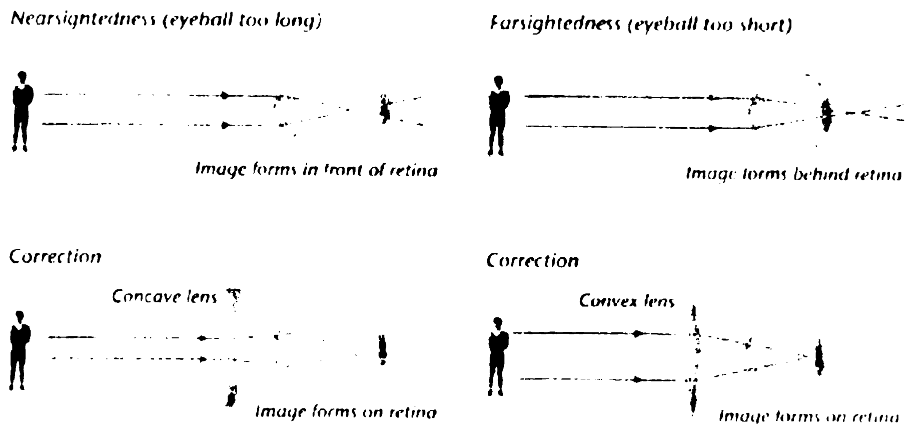


Adjust the shape of the lens until you get a clear image of the letter on the back of the eye.

Make the eye longer by pushing the syringe in slowly. This makes the lens of your eye thicker so the image forms in front of the retina and is blurry. Therefore, the eye is too long and is now nearsighted (can only see things up close).

There are 2 ways to correct this problem without having laser surgery, which changes the shape of the lens.

1) Move the letter closer to the eye.
2) Use a corrective lens, in this case the thicker concave lens with the strength –2.0D. Put the lens in the holder and the picture should become sharp again.
(See the diagram below)



Farsightedness
Place the letter 30cm from the eye and adjust the syringe to get a clear picture.

Make the eye shorter by slowly pulling the syringe out. This makes the lens of your eye thinner so the image would form behind the retina. Therefore the eye is too short and the image we get on the retina is unclear.

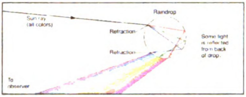
The picture will become sharp again if you correct the defect with a convex lens (+2.0D). (See the diagram above)

Go to Student Record.

RAINBOWS: The Refraction and Reflection of Light

Activity 5

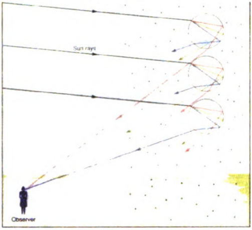
A rainbow is formed when light rays are refracted by different amounts as they enter the raindrop, then reflected at the back of the raindrops, and refracted again as they leave.
(See diagram A)



A Raindrop Produces a Spectrum

Diagram A

One raindrop produces a spectrum, but only one color is in our line of sight so that several raindrops are needed to produce a rainbow.
(See diagram B)



Raindrops Combine to Produce a Rainbow

Diagram B

Sometimes when the sun is lower in the sky light rays enter near the bottom of the first surface of a raindrop and the light is reflected twice before reemerging and a primary and secondary rainbow is observed.
(See diagram C)

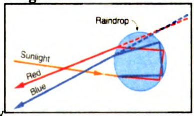


Diagram C

The primary rainbow has red on the outside and violet on the inside. The secondary rainbow has the colors reversed.
(See diagram D)

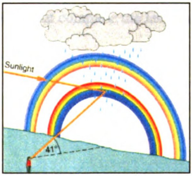
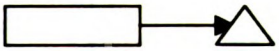


Diagram D

Using the light box and the prism make a rainbow



You may have to rotate the prism to get the best rainbow.

Notice the refraction and reflection as the light goes through the prism.

Activity 6

Addition of Colors
For this activity you will need the light box and the color filters.

Do not leave the color filters in the light box for more than 30 seconds, the heat from the lamp will damage the filters.

Use the side positions and the end of the light box to project 3 colors.

If you only need to project 2 colors close one of the flaps but make sure to remove the color filter first.

The end light is most intense so try to keep the weakest(lightest) color there.

Red, Green and Blue are the **primary colors of light** because when you combine them you get white light. Try it and see for yourself.

INFO

Refer to the info card on the *color of light and pigments* to see the difference between the primary colors of light and paint pigments.

When you mix any 2 primary colors you get the **secondary colors of light**, which are **magenta, yellow and cyan.**

RECORD

Use the light box to determine the 2 primary colors you need to mix to give each secondary color.
When you have figured it out complete the diagram in your student record.

Pairs of colors that mix to form white light are called **complementary colors**. Find the complementary colors for yellow, green and cyan. Record.

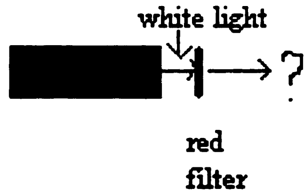
RECORD

Now use the light box to find the colors that complete the last diagram.

Subtraction of Colors

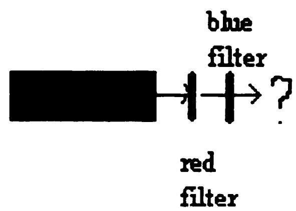
When you place a single filter in front of white light, the color of the filter is the only color you see, all other colors are **subtracted** from white light.

Try it with a red filter and see.



Try some other filters just to verify the color.

Now lets combine filters to see what colors are subtracted out and what color results.
Refer to your student record sheet to see what filters to combine.



Polaroid Filters

Activity 7

Picture yourself on the shore of a lake on a beautiful clear day. Sunlight is reflected off the sparkling water, making you squint. You put on a pair of polarizing sunglasses and the glare disappears. Now you can even see into the water. How can a pair of sunglasses make such a difference? Sunglasses that eliminate glare contain polarizing filters.

INFO

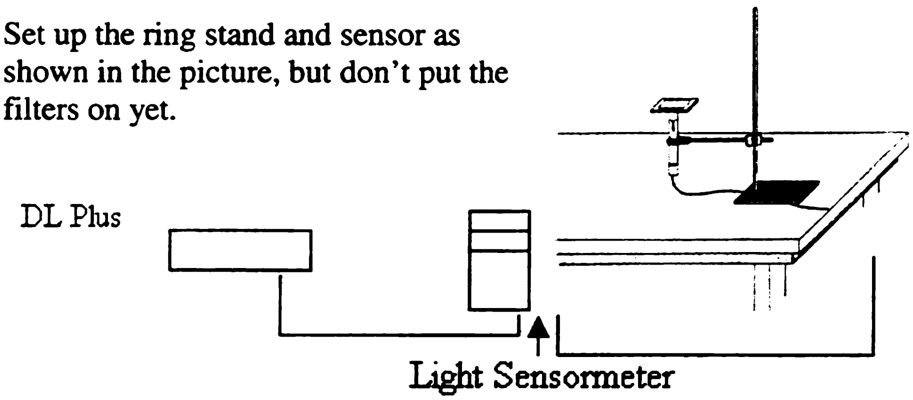
In this activity you will be experimenting with Polaroid filters to see how they filter light.

Get out the Polaroid filters, ring stand, light sensor, light sensor meter and the DL Plus.

Hook up the light sensor to the Light Sensormeter.

Connect the Sensormeter to channel 1 on the DL Plus.

Set up the ring stand and sensor as shown in the picture, but don't put the filters on yet.



Turn on the Light Sensormeter.

Set the range on the Sensormeter at 0 to 1000.

RECORD

Record the light level without any filters.

Put the 2 Polaroid filters together and look up towards the light.

Turn the top filter so that the most light gets through.

Place the filters on top of the sensor as shown above.

Change the range on the Sensometer to 0 to 100.

You are going to slowly turn the top filter 360° while holding the bottom filter in place. Be careful that you hand doesn't block the light.

Hit **enter** to wake up the DL Plus.

When you are ready press **record** on the DL Plus.

Begin turning the filter, when you have done one complete turn, press **record** again and go to **Stop and Save Data.**

Enter a file name and press **esc** when you are done.

Repeat the steps on this page again.

After you have made 2 recordings, take the DL Plus to the computer at the Velocity and Power station and hook it up. You may have to unhook the DL Plus that is at that station.

On the computer screen, double click on Datadisc Pro.

Under **File** go to **transfer.**

Highlight your file and click **ok.**

Print you graph.

Repeat the last 3 steps for the second set of data.

Before going to your student record, go to Mrs. Coyne's Web site.
(**http://hobbes.lite.msu.edu/~Coyne**)
Click on MSU Lecture Online.

To Login type: Username: **demo**
Password: **demo**
Class: **phy232c**
Click on Welcome.
Click Ch. 8 Electromagnetic Waves.
Go to 8.14 Applet: Polarization.

You can choose the number of filters you want and change the degree of each one. Take the time to try different things and make sure you really understand what is happening with Polaroid filters.

RECORD

Go to your student record.

INVERSE SQUARE LAW OF LIGHT

Activity 8

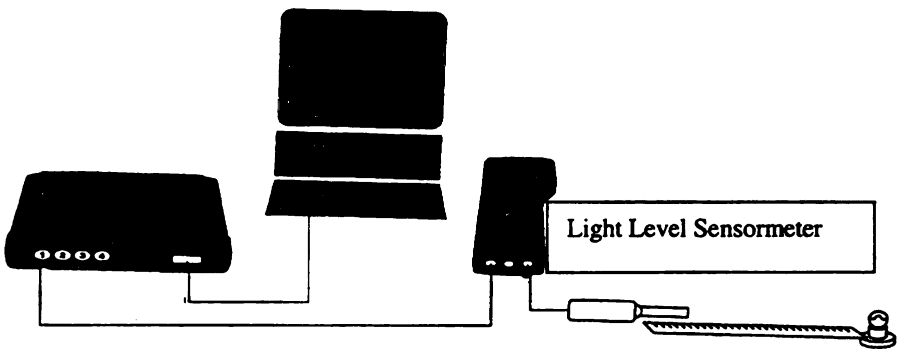
Light intensity is often referred to as *brightness*. Intensity is defined as the rate at which energy is transferred per unit area, measured in lumens per square meter or lux.

As you move away from a light source, the energy associated with it tends to spread out. Consequently, the intensity of the light, I, decreases as the distance from the source, r, increases. This relationship is expressed in terms of an inverse square law:

$$I = \frac{k}{r^2}$$

where k is a constant that depends on the physical characteristics of the light source.
In this lab, you will use the light sensor to verify the relationship stated above.

You will need: Datadisc, DL Plus, light sensormeter
penlight & a standard light bulb
1 meter stick



Set up the apparatus as shown in the diagram in a darkened area. Take care to have the center of the sensor level with the middle of the lamp, use the wooden block if needed.

Plug DL plus into the serial port of the computer. Connect the Light level Sensormeter to channel 1 of DL plus. Switch the Sensormeter **ON** and select range 0 to 100 lux. The actual range will depend the brightness of the lamp, but do not use log range.

Load Datadisc PRO

Click on the **MEASURE** menu bar. Select **CALIBRATE.** Make sure channel 1 has Light level/ lux, then click Channel **5**. Skip the options box, it should be on **enter calibration**. In the bottom right-hand you should enter the following:

Channel name:	distance	OK
Channel unit:	m	OK
min value:	0	OK
max value:	1.5	OK

Click on **OK. Close.**

Click on the **MEASURE** menu bar. Select **RECORD.**

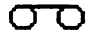
	x-axis	y-axis	
Select Light level for the y-axis.		√	Channel 1: Light level/ lux
Select Distance for the x-axis.	√		Channel 5: distance/ m

Click **Next**, you don't need to keep track on time so mark **no** and click **Next.** Click **Finish.**

Place the probe next to the lamp, distance 0 m.

Click on **X=** and enter **0** for the distance.

Click on record icon  **or** the spacebar when you are sure the distance is accurate. Since you are moving in regular distance intervals you will want to use X+ which will automatically add .05m to each reading. So before you move the sensor back to .05m put **0.05** in the box next to **X+**.

Move the probe .05m away from the lamp and click  or hit the spacebar.

Repeat the last step until you get 1meter away. Press **Finish** when complete. Click **Keep this data.**

Use the **SAVE** option from the File menu to save the data.

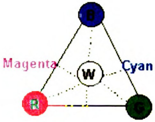
Repeat the process using a different light bulb.

Print out a copy of each graph and put on your student record sheet. You may need to shrink the graph down to fit the space provided.

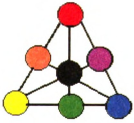
INFO

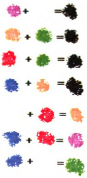
COLOR OF LIGHT & PIGMENTS

PRIMARY COLORS OF LIGHT



PRIMARY COLORS OF PIGMENTS

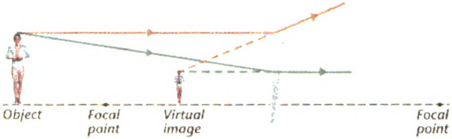




INFO

CONCAVE LENS

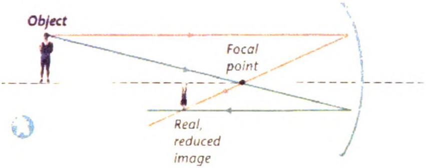
A concave lens refracts rays of light so that they appear to come from one of the focal points. The image formed by a concave lens is *always* a virtual image.



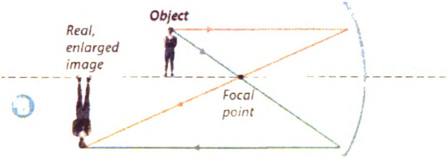
INFO

CONCAVE MIRROR

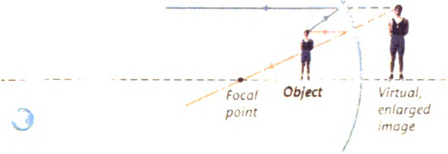
The type of imaged formed by a concave mirror depends on the position of the object in relation to the focal point.



A, B.
If the image is farther from the mirror than the focal point, the image is real and inverted.



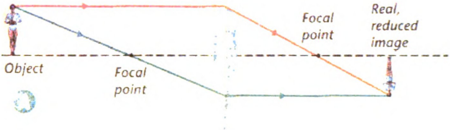
C.
If the object is between the mirror and the focal point, the image is virtual and upright.



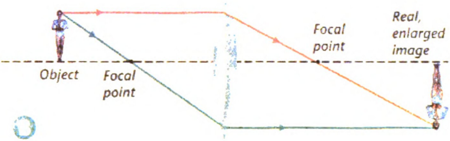
INFO

CONVEX LENS

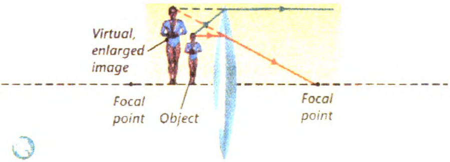
The type and size of the image formed by a convex lens depends on the position of the object.



A, B.
If the image is farther from the focal point than the lens, the image is real and inverted.



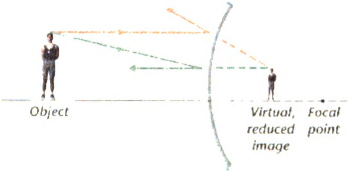
C.
If the object is between the focal point and the lens, the image is virtual.



INFO

CONVEX MIRROR

The image formed by a convex mirror is *always* a virtual image.



INFO

ELECTROMAGNETIC SPECTRUM

INFO

POLAROID FILTERS

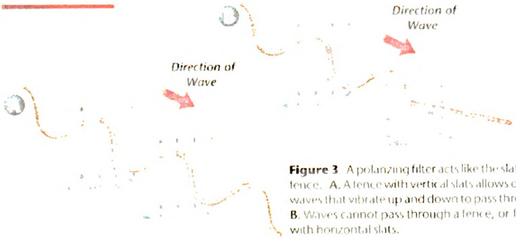
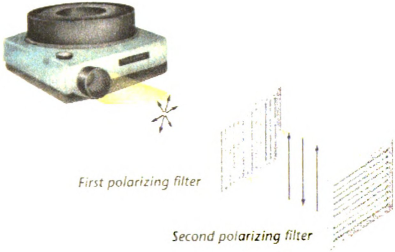
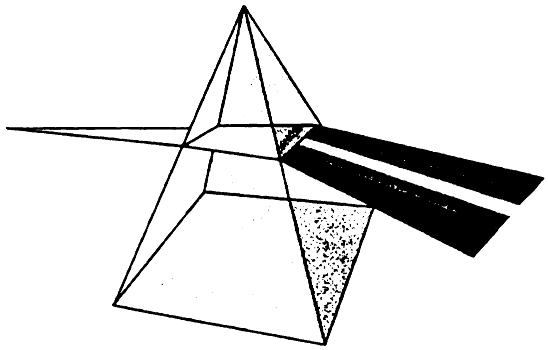
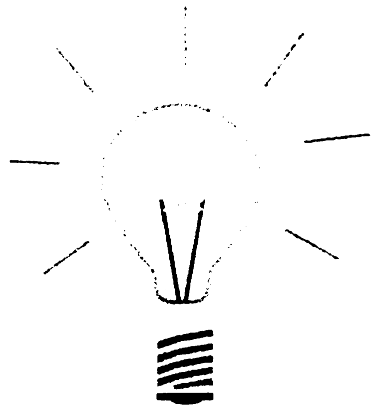


Figure 3 A polarizing filter acts like the slats in a fence. **A.** A fence with vertical slats allows only waves that vibrate up and down to pass through. **B.** Waves cannot pass through a fence, or filter, with horizontal slats.

The first polarizing filter allows only waves that vibrate up and down to pass through. When a second polarizing filter is placed at a right angle to the first, no light passes through.





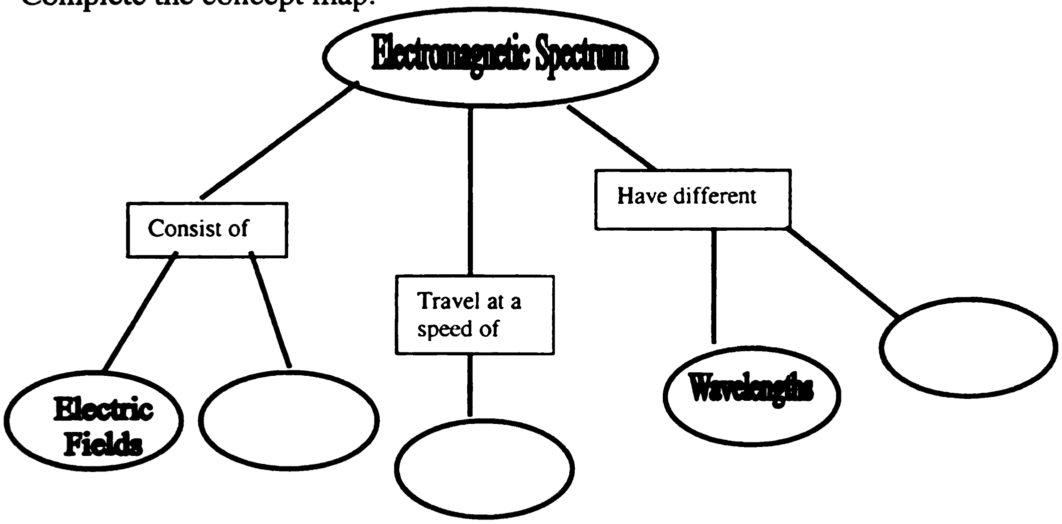


Light

Student Record

Student Record
Activity 0: Electromagnetic Spectrum

Complete the concept map.



Score Possible
6

What happens to the wavelengths as you go from radio waves to gamma rays? ________________

What happens to the frequency? _____________

Score Possible
6

What color of visible light has the longest wavelength? ____________

What color has the shortest wavelength? ____________

Score Possible
4

Which has a higher frequency red or violet light? ___________

Score Possible
2

Student Record
Activity 1: Plane Reflection

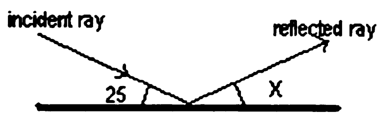
Drawing:

Score Possible
10

Angle of Incidence = ______° Angle of Reflection = ______°

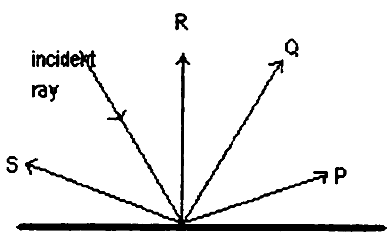
Score Possible
4

Without using a protractor, what in the measurement of angle X? ______



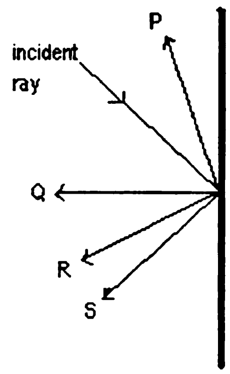
Score Possible
2

Which is the correct reflected beam P, Q, R, or S? ______



Score Possible
2

The incident ray has changed position, which is the reflected ray? _____



Score Possible
2

Devise a rule for the reflection of light from a flat mirror.
Here is a start:

The angle of incidence is always __________ the angle of reflection.

Score Possible
2

Specular vs. Diffuse

Explain what causes diffuse reflection?

Score Possible
4

List 4 surfaces on which specular reflection occurs and 4 surfaces on which diffuse reflection occurs.

Specular: ________, ________, ________, ________
Diffuse: ________, ________, ________, ________

Score Possible
8

Which type of reflection is more common? ____________

Score Possible
2

Why do you think so?

Score Possible
4

Student Record
Activity 2: Curved Mirrors

Concave Mirrors

Drawing:

Score	Possible
	10

focal length = ______

Score	Possible
	2

Draw a diagram to show the locations of the candle, the index card
And the concave mirror when the image was the clearest.

Score	Possible
	6

Is the image *real* or *virtual*? _________

Score	Possible
	2

Drawings:

1. small image

2. same size

3. large image

Score	Possible
	18

Convex Mirrors

Drawing:

Score Possible
10

focal length = ______

Score Possible
2

Does a convex mirror form a *real* or *virtual* image? ______

Score Possible
2

Why do you think so?

Score Possible
4

Student Record
Activity 3: Refraction

Is there any refraction at either the incident or emergent (where the light comes out on the other side) faces when the light hits the slab at a 90° angle? ________________

Score	Possible
	2

What other condition (besides a ray passing from one medium to another) must be present for refraction to occur?

Score	Possible
	4

Drawing:

Score	Possible
	10

Measure of <i1 = _______°

<r1 = _______°

<i2 = _______°

<r2 = _______°

Score	Possible
	8

Using the formula below calculate the **index of refraction** from air to acrylic and from acrylic to air.

$$\text{refractive index} = \frac{\sin i}{\sin r}$$

refractive index = __________ for air to acrylic
refractive index = __________ for acrylic to air

Score Possible
6

The index of refraction in a vacuum is 1. Why is one of your index of refraction less than 1 and one greater than 1?

Score Possible
6

Convex Lens
Drawing:

focal length = ______

Score Possible
10

Concave Lens
Drawing:

focal length = ______

Score Possible
10

Do you think a concave lens produces *real* or *virtual* images?_________

Score Possible
2

Student Record
Activity 4: The Eye

Video: Inside the Eye

On what part of the eye is the image found? __________

Score Possible
2

Is the image upright, inverted, or sideways when its projected on the retina? __________

Score Possible
2

When you are viewing objects very close to the eye, is your lens thin or thick? ________

Score Possible
2

When you are viewing objects far away from the eye, is your lens thin or thick? ________

Score Possible
2

What is the colored part of the eye called? __________

Score Possible
2

What is the shape of the iris when exposed to bright light? __________

Score Possible
2

What is the shape of the iris when exposed to very dim light? __________

Score Possible
2

What does the brain do to the position of an image? _________________

Score Possible
2

How do concave lenses correct Nearsightedness?

Score Possible
4

How do convex lenses correct Farsightedness?

Score Possible
4

STUDENT RECORD
Activity 5: RAINBOWS

List the order of the colors from the outside to the inside of the rainbow.

Score Possible 3

____

____

Which color is refracted the most? ____________________

Score Possible 2

Trace the ray of light through the drop of water. What happens to the order of the colors as the ray is reflected through the body of the raindrop?

Score Possible 4

Where must the sun be and where must the raindrops be in order for you to see a rainbow?

Score Possible 4

Why don't we see a rainbow to our south?

Score Possible 4

Why do we rarely see a rainbow at noon?

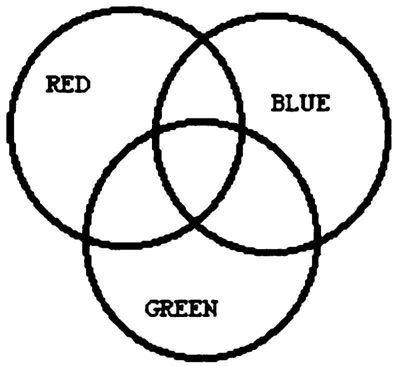
Score Possible 2

Explain how <u>refraction</u> and <u>reflection</u> are responsible for forming a rainbow. Define both terms in your answer.

Score Possible 8

Student Record
Activity 6: Colors of Light

Addition of Colors

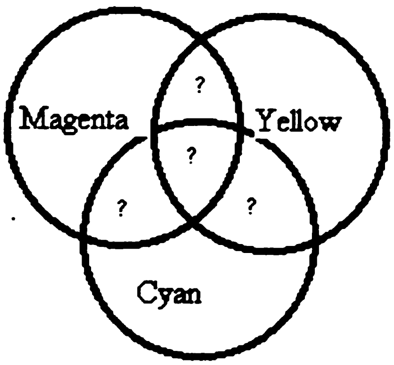


Score Possible
8

Yellow + __________ = White
Green + __________ = White
Cyan + __________ = White

Score Possible
6

Fill in the question marked area with the appropriate color.



Score Possible
8

Subtraction of Colors

Red and Blue leaves ____________
Yellow and Blue leaves ____________
Red and Magenta leaves ____________
Cyan and Green leaves ____________
Orange and Magenta leaves ____________

Score Possible
10

Student Record
Activity 7: Polaroid Filters

Light level of the room without the filters is _________.

Score Possible
2

Attach your graphs to the back of this sheet.

Score Possible
10

Describe your graphs.

Score Possible
5

How many crests does each graph have? _______

How many troughs? _______

Score Possible
4

There are 360° in a complete turn. How many degrees did you turn the Polaroid filter to cause the light intensity to go from maximum value (crest) to minimum value (trough)? _________

Score Possible
4

Light is partly polarized when reflected from some flat surfaces such as water. Why are Polaroid sunglasses especially effective on water?

Score Possible
5

STUDENT RECORD
Activity 8: INVERSE SQUARE LAW OF LIGHT

Graph 1.

Score	Possible
	5

Graph 2.

Score	Possible
	5

Use your data from you penlight graph to verify the Inverse Square Law by solving for *k* for the data points listed. $k = I \bullet r^2$

Distance (meters)	Intensity	*k*
0.0		
0.05		
0.10		
0.15		
0.2		
0.25		
0.30		
0.35		
0.40		
0.45		
0.50		
0.55		
0.60		
0.65		
0.70		
0.75		
0.80		
0.85		
0.90		
0.95		
1.00		

Score Possible
10

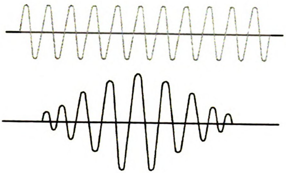
Review your values for *k*, how do they compare? Explain using the Inverse Square Law.

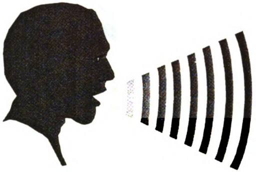
Score Possible
5

List several physical characteristics of a light source that you suspect might have an effect on its intensity at a fixed distance from the source.

Score Possible
5

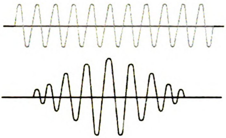
Waves/Sound

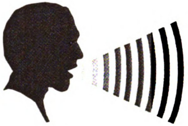




Student Record

Waves/Sound Objectives





At the end of this unit you should:

- Be able to explain what a wave is and how it travels.
- Be able to explain the difference between transverse and longitudinal waves.
- Know the properties of transverse and longitudinal waves.
- Understand the reflection of sound waves and their application.
- Understand how sound waves are diffracted.
- Understand why waves refract and what happens to the wave when they do.
- Understand interference patterns of sound waves and their application.
- Explain the difference between pitch and loudness and the properties that affect each.
- Know what Doppler Effect is and be able to explain how it is caused.

Waves: How do they travel?

Activity 1

INFO

A **wave** is a disturbance that transfers **energy** from place to place. Energy is the ability to do work. If you were floating on a raft on a lake, the energy carried by a water wave can lift you up as the wave passes.

The material through which a wave travels is called a **medium**. Gases, Liquids and Solids all act as mediums. Water waves and sound waves require mediums. Electromagnetic waves, which include light waves, do not require a medium. They travel through empty space. You will learn more about light and electromagnetic waves at the light station.

When a wave does travel through a medium such as water, is the medium actually moving with the wave?

Let's use the ripple tank and a piece of styrofoam and see.

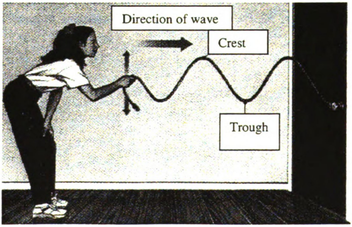
Using only one dipper turn the wave generator on slowly causing the medium to vibrate, creating a wave.
Place the styrofoam in the water.
If the medium (water) is moving the styrofoam should move across the wave table.

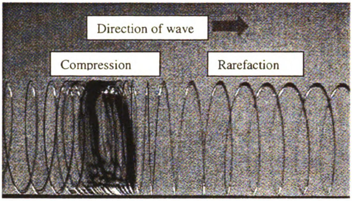
Once you have observed and understand what is happening, go to your student record sheet to answer a couple of questions.

RECORD

Types of Waves
Waves are classified by how they move. There are 2 types of waves, **transverse waves** and **longitudinal waves** (sometimes called compressional waves).

Transverse waves move the medium at right angles to the direction in which they are traveling.





Longitudinal waves move the medium in the same direction that the waves are traveling.
To see the difference between them go to Mrs. Coyne's web-site. (http://hobbes.lite.msu.edu/~Coyne)
Click on **BYU Physics Applets**.
Double click on **Transverse and Longitudinal Waves**.

Click on the file tab labeled Transverse and Longitudinal Waves.

Click on the circle next to Transverse and then play to see a transverse wave.
Click on the circle next to Longitudinal and the play to see a longitudinal wave.

To find out more information about the 2 types of waves go back to Mrs. Coyne's web page and click on **MSU Lecture Online**.

To login type: Username: **demo**
Password: **demo**
Class: **phy231c**

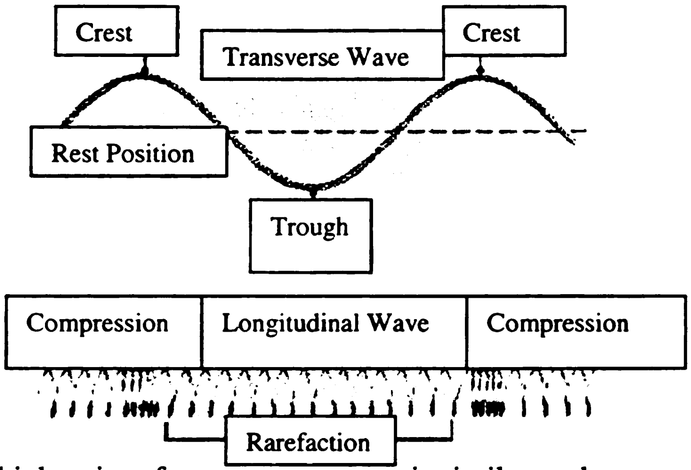
Click the ∇ next to Welcome.
Click on Ch.13 Vibrations and Waves
Click the ∇ next to 13.1 Vibrations and Waves
Click on 13.14 Wave Characteristics

RECORD

Go to your student record.

Activity 2

Wave diagram:

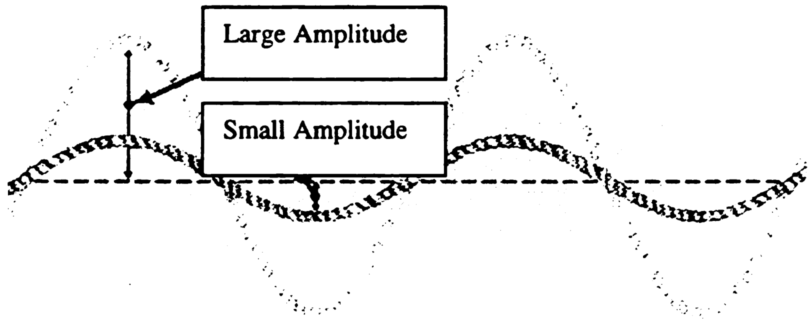


The crest or high point of a transverse wave is similar to the compression in a longitudinal wave.

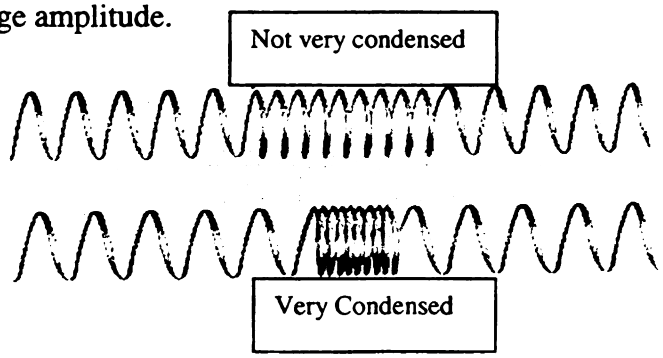
The trough or low point of a transverse wave is similar to the rarefaction part of the longitudinal wave.

Amplitude

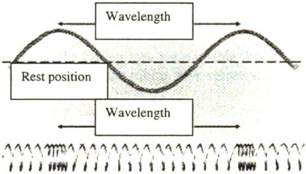
The amplitude of a transverse wave is the distance from rest position to a crest or trough.(see below)



The amplitude of a longitudinal wave is a measure of how compressed or rarified the medium becomes. If the compressions are crowded the wave has a large amplitude.



Wavelength



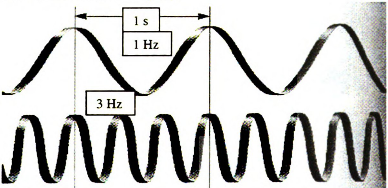
The wavelength of a transverse wave is the distance form crest to crest or trough to trough.

The wavelength of a longitudinal wave is the distance from compression to compression.

RECORD

Go to your student record.

Frequency
Frequency is the number of vibrations produced in a given amount of time and is measured in Hertz(Hz).



The wave on the bottom has a wavelength one-third that of the wave on the top, while has a frequency three times as great.

Speed

Speed = Wavelength x *Frequency*

$$v = \lambda \times f$$

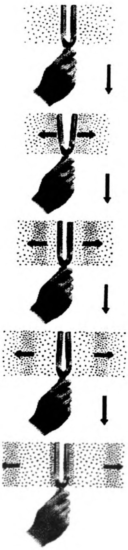
RECORD

If you increase the wavelength or frequency you increase the speed.

Go to your student record to answer some questions on the properties of waves.

Longitudinal Waves

You have gone over the properties of both longitudinal and transverse waves, but now you are going to concentrate on longitudinal waves. You will learn more about transverse waves at the light station.



If the air around a tuning fork were visible this is what you might see as the tuning fork vibrates.

When the tines of the tuning fork move out you get a compression because the air particles are getting pushed together.

When the tines move toward each other the air particles are allowed to stay spread out and you get a rarefaction.

This pattern repeats as the tuning fork continues to vibrate.

It is similar to what happens when you push and pull a slinky.

Get the slinky from your teacher.

Read through the description next each diagram on the following page. Do steps (a-d) with your slinky.

See if what you observe matches the diagrams.

a. Mario & Kate hold the stretched slinky on the floor.
b. Mario gives a quick push of the slinky toward Kate. He the pulls it back quickly to its original position.
c. When the slinky is still, Mario pulls the slinky back and then quickly returns it back to its original position.
d. Mario pushes his end quickly. He then pulls it back quickly as far past the starting position as he pushed it forward. He then quickly pushes the slinky back to the starting position. Mario has produced one complete vibration. This is like a sound wave, one compression and one expansion together create a sound wave.
e. Mario produces two complete vibrations.

Go to your student record to answer some questions about what is happening with the slinky.

Reflection

Activity 3

When a sound wave hits a surface that it cannot pass through, it bounces back or reflects. The reflected sound wave is called an **echo**.

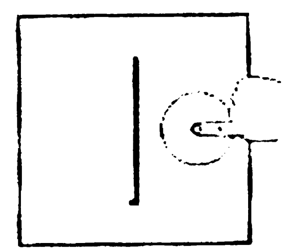
In this activity you are going to use the Ripple Tank to show different types of reflection.

Turn the power supply for the ripple tank on.

The lamp should be on but leave the wave generator motor and stroboscope off.

Circular Pulse

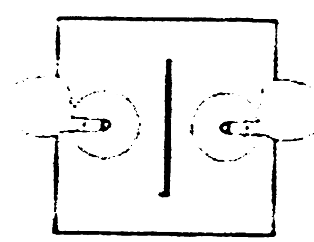
Using a straight barrier in the middle of the tank, dip your finger in the water to produce a single circular pulse.



Look at the white board under the wave table to observe the wave pattern.

Draw the reflected pulse.

Make 2 pulses at the same time on each side of the barrier and draw the reflected pulses.



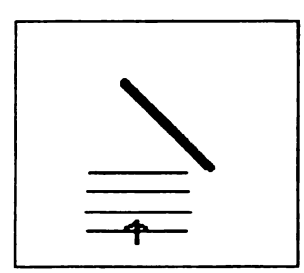
Plane Pulses

Place a long straight barrier in the center of the ripple tank, parallel to the lamp support rod.

Use the single blade to create a pulse parallel to the barrier. Gently push down on the wave generator with your hand to make on pulse.

Observe the reflected waves. Go to your student record.

Turn the barrier ~20°.



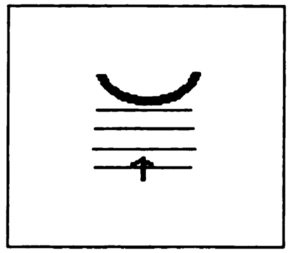
Send single pulses toward the barrier.

Observe.

Change the angle further and repeat.

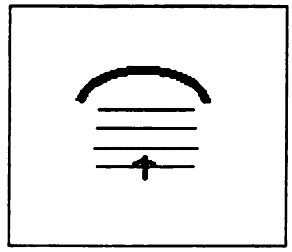
Curved Barriers

Place the clear plastic circular reflector in the center of the tank, with the **convex** side toward the source as shown.



Make single plane pulses, observe and draw the reflected pulses.

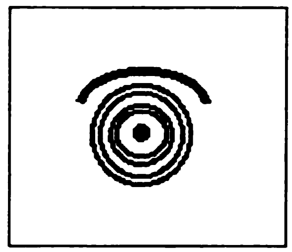
Reverse the reflector so the **concave** side is facing the pulses.



Make single pulses.

Draw the reflected pulses.

In the last step, you should have observed the waves coming together and meeting like the middle of a circle. Repeat the last step and try to put your finger at the point where the waves meet.



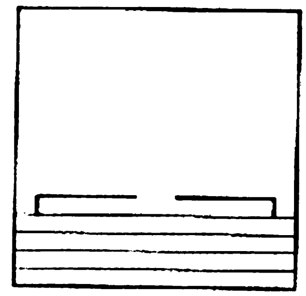
Without moving the reflector, use your finger to make circular pulses at the point you have marked.

Draw the reflected waves.

Activity 4

When a wave passes a barrier or moves through a hole in a barrier, it bends and spreads out. The bending of a wave around the edge of a barrier is known as **diffraction.**

Sound waves spread out when they pass through a doorway or hit a corner. We cannot see the diffraction of sound waves but we can use the ripple tank to show the diffraction of water waves so we can visualize how sound waves would behave.



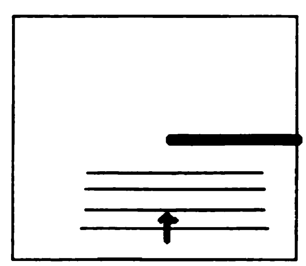
Set up the barriers as shown.

The opening in the middle is representative of a doorway.

Turn the wave generator motor on to send straight pulses (sound waves) toward the opening.

Turn the stroboscope on and adjust the speed of both the stroboscope and the wave generator to get the best picture.

Draw your observations.



Move the barriers against the edge of the tank to represent the corner of a wall.

Send plane waves at the barrier.

Use a long wavelength (low frequency) first and gradually increase the frequency (the speed of the motor) to decrease the wavelength.

Observe. Go to your student record.

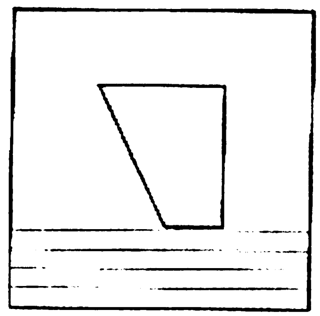
Refraction

Activity 5

Refraction is the bending of a wave. Refraction is due to the change in speed of a wave, as ocean waves approach the shore they enter shallow water and slow down. Since the ocean floor is uneven, some parts of the wave slows down at different times causing it to bend.

To show this, place the glass refraction plate on the wave table. Make sure there is enough water to just cover the plate to a depth of 1 or 2mm.

Send plane waves at the edge of the plate as shown.



You may have to adjust the speed of the wave generator and the stroboscope to get the best wave picture on the white board.

Observe the difference between the waves passing next to the plate and those passing over the plate.

Set the wave generator and the stroboscope so that the waves appear to be traveling slowly toward the plate.

Rotate the plate so the wave meets the edge of the plate at an angle.

Try different angles.

Go to your student record.

Activity 6

Interference occurs when 2 or more sound waves interact. The amplitudes of the 2 waves combine causing the loudness of the sound to change.

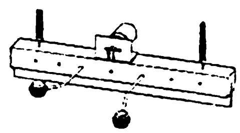
In **constructive interference**, compressions occur at the same place so the amplitudes combine and the sound is louder than either of the original sounds.

In **destructive interference**, the compression of one wave occurs at the same place as the rarefaction of another wave and the amplitudes cancel each other. The resulting wave is softer or completely concealed.

The way sound waves interact is very important in the design of concert halls.

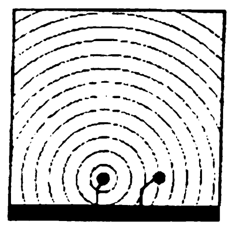
Interference is easier to see in transverse waves so again you will be using the wave table to show interference patterns.

Adjust the height of the wave generator so that the blade does not hit the water.



Put both dippers in but turn one so it doesn't touch the water.

Look at the pattern produced using a low frequency.



The stroboscope speed should be adjusted so the wave appears to stand still.

Turn the second dipper so it makes contact with the water and observe how the pattern changes.

Draw your observation on you student record.

Move the dippers farther apart. Go to your student record.

Go to Mrs. Coyne's web-site. (http://hobbes.litc.msu.edu/~Coyne)
Click on **MSU Lecture Online.**

To login type: Username: **demo**
Password: **demo**
Class: **phy232c**

Click the ∇ next to Welcome.
Click on Ch.11 Interference & Diffraction
Click the ∇ next to 11.1 Interference & Diffraction
Click on 11.4 Applet Interference

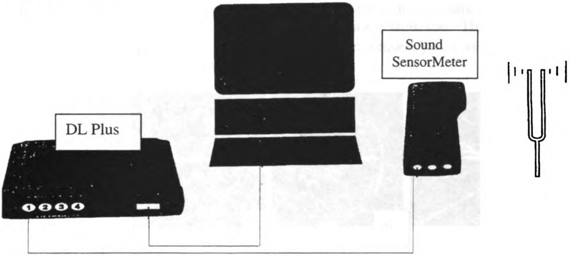
Scroll down, click on < or > to move the wave sources and observe the interference patterns.

Go to your student record and answer the rest of the questions.

Wave Analysis

Activity 7

In this activity you will be investigating a variety of sounds from a simple tuning fork to the human voice.



Plug DL plus into the serial port of the computer.

Load Datadisc PRO.

Plug the Sound SensorMeter into channel 1 of DL plus and switch **ON**. Use the 'down' arrow key on the SensorMeter to select wave.

On the computer screen click on the **MEASURE** menu bar. Click on **FAST**.

Select 12ms (61μs intervals). Select **No Trigger**. Click **OK**.

Strike the tuning fork and hold the base on the table next to the grill on the Sound SensorMeter. Have your partner click  or **Record.**

Click on **Finish** and show the expanded trace of the waveform.

Click on **Keep this data**. Use the number on the tuning fork for your title.
Select **Print** to print your graph now or use the **SAVE** option from the File menu to save the data and print it later.

Repeat the above steps with 2 more tuning forks.
Print all 3 graphs.

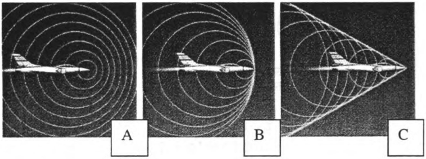
Investigate the waveforms of other sounds such as a whistle, musical instruments or the human voice. You do not have to print a graph but may need to use these to help you with the questions.

DOPPLER EFFECT

Activity 8

INFO

Have you ever been outside and heard a plane flying overhead?
Did you notice that the sound of the plane as it is coming toward you is different from the sound as it is going away from you. This is called the **Doppler Effect**, the apparent change in frequency as a wave source moves in relation to the listener.



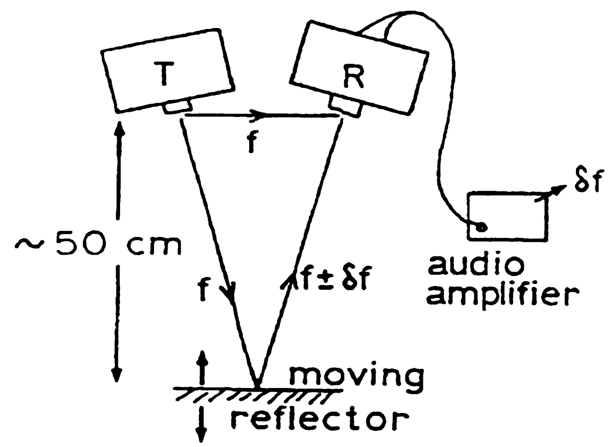
A. The waves are closer together in front of the plane so the will have a higher pitch. The waves behind the plane have a lower frequency and thus a lower pitch.
B. The plane is travelling almost as fast as the speed of sound and the sound waves are piling up in front of the plane.
C. When the plane flies faster than the speed of sound, it breaks through the pile-up of waves known as the sound barrier. When the sound barrier is broken it releases huge amounts of energy in the form of a shock wave. People on the ground nearby hear a loud noise called a *sonic boom.*

Go to Mrs. Coyne's Web-site. (http://hobbes.lite.msu.edu/~Coyne)
Click on **MSU Lecture on Line.**

To login type: Username: **demo**
Password: **demo**
Class: **phy231c**
Click the ∇ next to Welcome.
Click on Ch.14 Sound
Click the ∇ next to 14.1 Sound
Click on 14.16 Doppler Effect

Read the information on Doppler Effect.
Click **Demo** to play an example.
Make sure the speakers are on and click on play >.

Let's see if we can create our own Doppler Effect.
Set up the transmitter, receiver, reflector and audio amplifier as shown in the diagram below.



Move the reflector back and forth toward the transmitter.

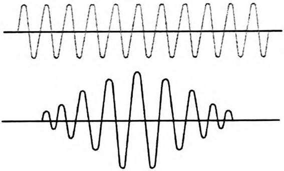
Some of the signal reaches the receiver directly, and some after reflection from a moving object. The latter is shifted in frequency, and the 2 different frequencies produce "beats" which can be heard through the amplifier.

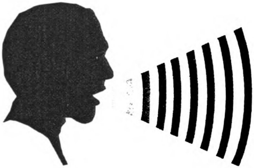
The beat frequency is proportional to the velocity of the reflector. This is the principle of the radar speed trap.

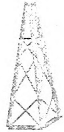
Make sure that everything is turned off when you are done, the batteries are only available through special order and are expensive!

Go to your student record sheet.

Waves/Sound







Student Manual

Student Record
Activity 1: Waves

In general, where do waves get their energy?

Score	Possible
	4

When a wave passes a duck floating on a lake,
how does the wave affect the duck?

Score	Possible
	6

Give an example of a transverse wave.

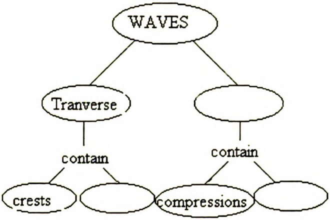
Score	Possible
	3

Give an example of a longitudinal wave.

Score	Possible
	3

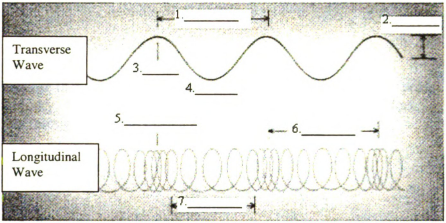
Student Record
Activity 2: Properties of Waves

Complete the concept map.



Score Possible
6

Label all the parts of the transverse and longitudinal waves.



Score Possible
14

How are a waves speed, frequency and wavelength related? Explain

Score Possible
6

Longitudinal Waves: Slinky

When Mario pushes as in (b), what happens to the slinky?

Score	Possible
	3

When Mario pushes as in (b), he gives energy to the spring.
What happens to Kate's hand when she receives the compression?

Score	Possible
	4

When Mario pulls as in (c), what happens to the coils of the slinky?

Score	Possible
	3

In (d) and (e), how is the energy Mario gives to his end of the spring passed along to Kate?

Score	Possible
	4

Suppose that air particles act like the turns of wire in a coiled spring or slinky. How would sound energy from a vibrating tuning fork pass through the air to the ear?

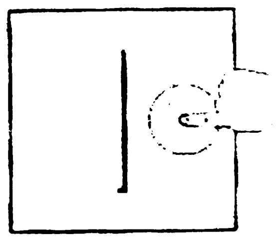
Score	Possible
	6

Student Record
Activity 3: Reflection

List 3 ways that echoes or the reflection of sound are used?

Score Possible
6

Circular Pulse

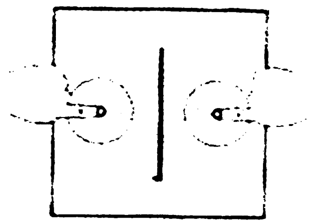


Score Possible
5

Where does the reflected pulse appear to have started from?

Score Possible
3

2 Circular Pulses



Score Possible
5

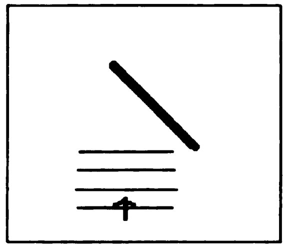
What do they appear to do as they meet the barrier?

Score Possible
3

Plane Pulses
Where does the reflected pulse appear to come from?

Score Possible
3

Draw what the reflected pulse will look like on the diagram.



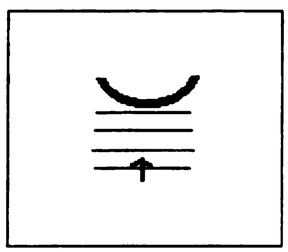
Score Possible
5

What is the connection between the angles of the incident pulses (the ones you produced) and the reflected pulses?

Score Possible
3

Curved Barriers

Convex Surface



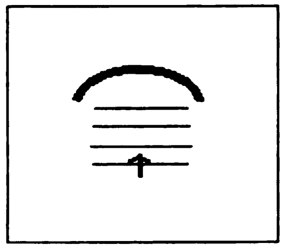
Score Possible
5

Where do the pulses appear to be coming from?

Score Possible
3

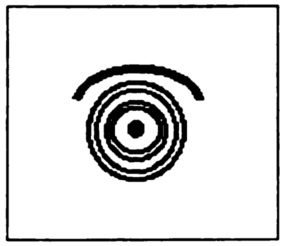
Concave Surface

Plane Pulse



Score Possible
5

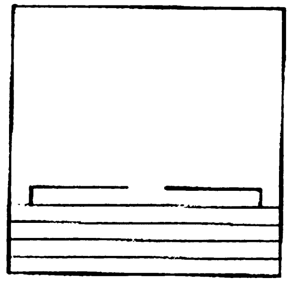
Circular Pulse



Score Possible
5

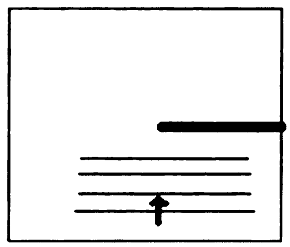
Student Record
Activity 4: Diffraction

Doorway



Score Possible
5

Corner of a wall



Score Possible
5

How does the behavior of the wave change as the wavelength decreases?

Score Possible
5

Student Record
Activity 5: Refraction

How is the speed of the waves affected by the depth of the water?

Score Possible
4

Use the formula $v = f \times \lambda$ (velocity = frequency x wavelength).
Since frequency is constant because it is set by the wave generator, what is the relationship between velocity (v) and wavelength (λ)?

Score Possible
4

What happens to the wavelength as the waves pass into deep water again?

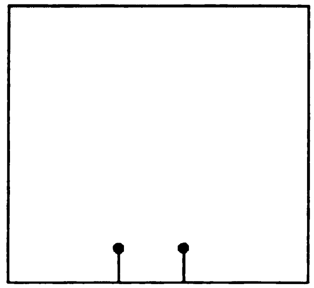
Score Possible
4

What happens to the waves when the hit the plate at an angle?

Score Possible
4

Student Record
Activity 6: Interference of Sound Waves

Draw your observations.



Score Possible
5

Describe you observations.

Score Possible
5

What is the effect of moving the dippers further apart?

Score Possible
4

Explain the dark and light areas of the interference patterns.

Score Possible
6

Can you have both constructive and destructive interference in the same interference pattern? Explain

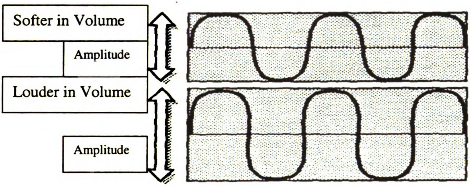
Score Possible
5

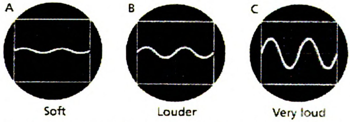
STUDENT RECORD
Activity 7: Wave Analysis

Tape a print out of the tuning fork graphs to this page.

Score Possible
15

The louder the sound the higher the crests and troughs. The crests and troughs are indicators of the **amplitude**, which in turn determines the **loudness** of the sound. The sensor measures in amplitude. (See diagram below)





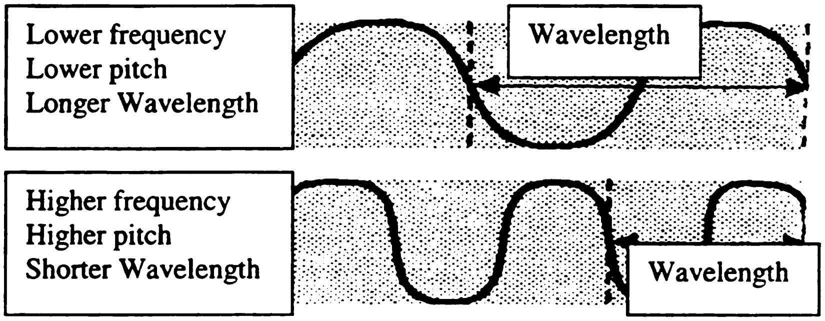
Looking at your graphs, which tuning fork was the *loudest*?

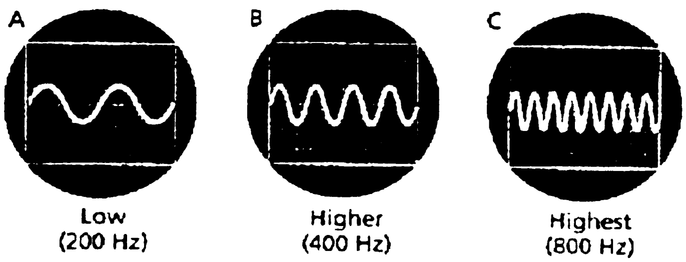
Score Possible
3

Which tuning fork was the *softest?*

Score Possible
3

It is also necessary to be aware of the **frequency** of the waves. Sounds may have the same loudness but a different frequency, such as different musical notes. Therefore their **pitch** is different.
(See the diagram below)



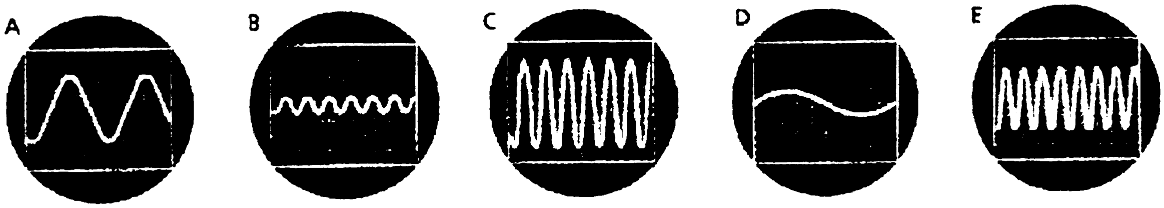


Looking at the wavelength, which tuning fork had the *highest* pitch? (Listening to each one may also help)

Score Possible
3

Why does this tuning fork have a higher pitch? Are the tongs shorter/longer and how does that affect the sound waves produced?

Score Possible
6



Match the screen displays above with each of the following:

_____ a sound that is both soft (quiet) and high-pitched

_____ a sound that is both loud and low-pitched

_____ a sound that is loud and high-pitched

_____ a sound that is both soft and low-pitched

Score	Possible
	8

Which screen display shows the lowest sound?

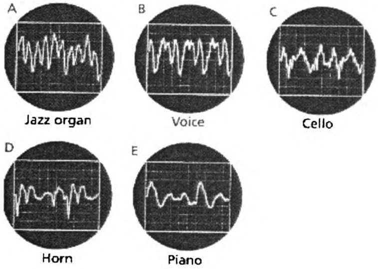
Score	Possible
	2

Which screen display shows the softest sound?

Score	Possible
	2

Which two screen displays have the same pitch?

Score	Possible
	4



What are 2 similarities in the displays?

Score Possible
6

What differences are there among the wave patterns?

Score Possible
3

Why are the patterns different?

Score Possible
3

STUDENT RECORD
Activity 8: Doppler Effect

Explain the Doppler Effect as it applies to a police car, with its sirens going, passing in front of your house. Make sure you explain what is happening to the sound waves and include a drawing.

Score Possible
10

Drawing:

Score Possible
10

Can you think of a use of the Doppler Effect other than a radar speed trap? (Hint: You see it on the news everyday.)

Score Possible
4

CONSENT FORM

August 25, 1999

TO: Physical Science Parents and Student
FROM: Mrs. Deb Coyne (Physical Science teacher)
RE: Request for the use of student work in a Master's thesis paper.

For the past four summers I have been working toward my Master's in Physical Science Education. This past summer I have spent writing two units, one focussing on light and the other on sound. The purpose of these units is to enable to the student along with their partner to take an active part in their learning and to come to an understanding of the topic through student directed activities rather than teacher directed lecture. In order to complete my thesis I must collect data from the student's work. This data will be collected for approximately four weeks, two weeks while they are at the light station and two weeks while they are at the sound station. The data collected will consist of a pre-test, mid-test, post-test, samples of student work and a short survey after they have completed each unit. In order to protect the privacy of the students, names or distinguishing characteristics will not be used in my thesis. All samples of student work and scores will be kept confidential.

Please understand that if you do not wish to have your scores or responses used, you will not be penalized. However, for those who choose to participate, I appreciate it. If you have any concerns or questions please feel free to contact me at 794-4906.

Sincerely,

Mrs. Deb Coyne

______ I give Mrs. Coyne my permission to use any of my data in her thesis. I understand that my name will not be used and my data will remain confidential.

______ I do not wish to participate. I understand I will not be penalized.

____________________	__________
Student Signature	Date
____________________	__________
Parent or Guardian Signature	Date