This is to certify that the

thesis entitled

LIGHTS! SOUND! PHYSICS!
A BASIC PHYSICS CLASS FOR HIGH SCHOOL

presented by

Kathryn Ebrahimi

has been accepted towards fulfillment
of the requirements for

Master's degree in Physical Science-Interdepartmental

Major professor

Date 24 Sept 02

O-7639

LIGHTS! SOUND! PHYSICS!
A BASIC PHYSICS CLASS FOR HIGH SCHOOL

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Division of Science and Mathematics Education

2002

ABSTRACT

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The purpose of this project was to determine whether student projects would help increase student understanding and application of the physics wave concepts. During the marking period spent on waves, students worked on projects as well as on traditional labs. The traditional labs were used only as an introduction to the topic. The projects were used to help assess student learning and comprehension of the topics. The students created and played their own instruments for the sound section of the unit. For the light section of the unit, the students worked in groups to create a laboratory experiment, game or demonstration illustrating a specific concept. Along with traditional homework and tests, evaluation of student learning was based on the laboratory reports the students wrote for their projects, as well as whether or not they were able to create a working instrument, laboratory experiment, game or demonstration. The students were quite receptive to the projects, and attacked them with enthusiasm. The results according to the grades and surveys show the effectiveness of the projects in aiding the students' learning.

ACKNOWLEDGEMENTS

I would like to thank my family and friends for their support and encouragement not only during my Master's work, but from the time I started working on my Bachelor's Degree. My heartfelt gratitude is also extended to the Towsley Foundation whose financial support made my studies possible. I also would like to thank the wonderful staff of the DSME for their time, support and dedication. Finally, a special thank you to my wonderful students from Roosevelt High School who made this project a joy and remind me every day why I am a teacher.

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INTRODUCTION

I. Rationale

When I started teaching physics at Theodore Roosevelt High School, I inherited a tradition. The physics students would build and race mousetrap-powered cars against the Advanced Machine Shop class. While the students really enjoyed this race and making their cars, I wondered if building the cars really helped the students understand the physics concepts behind their creations. Concerns that learning was robust and met the Michigan Standards and Benchmarks were foremost in my mind. How could I be sure that making projects was the best way for students to learn in order to insure and determine that the benchmarks were being met?

Not wanting to tamper with tradition, I converted the way another unit was taught, to include student driven projects. I chose the unit on the physics of waves. Instead of the usual sound and light laboratory experiments, I decided to incorporate projects to help assess the students' understanding of these concepts. Along with using projects, which based on my experience with mousetrap cars, most students seemed to enjoy, I had other reasons for rewriting the unit on the physics of waves. An unusually high number of my physics students were either in drama, band, or vocal music through school or played an instrument on their own. Being able to relate their favorite subject and/or pastime, as well as other everyday phenomena, to physics was an opportunity too tempting to pass up. Physics also has been regarded by the general public as an esoteric subject suited only to the "smart" students who excel in math, a notion I have worked hard to dispel. The last reason that the sound and light unit was rewritten came from my own dislike of traditional physics labs, which seemed to have students perform an experiment following a given set of instructions, and then solve several mathematical equations to prove what they had just done. Traditional labs do not allow the students to discover, but to verify. The beauty of the physical concept was lost to students worrying if they had gotten the "right answer".

The goal of rewriting this unit on the physics of waves was to determine how well students learned and retained wave concepts. By focusing on projects, the students had to understand the ideas well enough to create and explain a musical instrument and a light laboratory experience, game or demonstration.

The unit on the physics of waves is broken into six chapters. Two of the chapters I taught almost as I have for the past six years. The introductory chapter, Vibrations and Waves, skims over basic concepts and provides base information that applies to both sound and light waves. I previously had developed discovery-based laboratory experiments for the chapter on color, so I did not rewrite that chapter. Through repeated teaching over the past six years, I found that the chapters on sound, light, reflection, refraction and lenses lent themselves best to revision. The discovery-based laboratory experiments I used to introduce these chapters were conceptual in nature and had very simple, if any, mathematics associated with them. The projects required formal reports, explaining the concepts as well as incorporating mathematics. Evaluation was provided in the form of homework, tests, and the laboratory reports.

II. Ideas on Teaching Physics

Determining whether projects and activities, rather than traditional laboratory experiments would enhance student learning was one reason I chose to rewrite the unit on sound and waves. Another reason was to help students see the reach of physics in their everyday lives, and dispel the notion that only the top students could benefit from or even pass physics. Indeed, physics is often thought to be a "weed out course, … a course to get through" (Hewitt, 1990). By focusing on activities and projects students get the opportunity to see the relationship between the ideas and concepts of physics in a real-world context. Working on projects and activities also can help students learn more effectively. As Lillian McDermott, Professor of Physics at Washington State University says, "Teaching by telling is an ineffective mode of instruction for most students. Students must be intellectually active to develop a functional understanding" (1993). One method of instruction that embodies this idea is known as the inquiry method. David L. Haury describes the inquiry method of science teaching by saying "From a science perspective, inquiry-oriented instruction engages students in the investigative nature of science…So, inquiry involves activity and skills, but the focus is on the active search for knowledge or understanding to satisfy a curiosity". He goes on to say that there is no meaningful learning if there is no inquiring mind seeking an answer, solution, explanation or decision. (1993). This idea lends itself to a constructivist model of education, one that embodies the belief that knowledge is constructed, not transmitted. Further, it is believed that building useful knowledge structures requires effort and purposeful activity (Umass, 2002). One good way for students to construct their own knowledge is by the use of projects related to the curriculum. In 1999, the Buck Institute for Education, a proponent of Project Based Learning, described project based learning as:

> Project based learning is an innovative model for teaching and learning. It focuses on the central concepts and principles of a discipline, involves the

> students in problem-solving investigations and other meaningful tasks, allows students to work autonomously to construct their own knowledge, and culminates in realistic products.

The unit I designed used different methods of inquiry or constructivist learning: discovery activities, experiments and project based learning.

The discovery activities were used to arouse curiosity and allow the students to "discover" some fundamental information about each topic. "One implication is that inquiry-oriented teaching begins or least involves stimulating curiosity or provoking wonder" (Haury, 1993). In the unit reported here, these activities were used at the beginning to introduce a new concept. In the experiments, the students were expected to find known results. For example, in the "Grandfather Clock" laboratory experiment, the students investigated how the period of a pendulum varied with it's length. However, all experiments contained open-ended questions and gave the students the opportunity to use learned or prior knowledge to solve a problem. Creating a project allowed the students to use all the information learned from the experiments, as well as conduct research on their own. In Project Based Learning the designing process of the individual project is critical to learning. In Project Based Learning students "construct their own knowledge, so it's easier for them to transfer and retain information." (Buck Institute of Education (B.I.E). 1999) In the next project, students used the information from the chapters to design working instruments. This allowed students to not only use present knowledge, but to apply the defining features of Project Based Learning as defined by the Buck Institute for Learning in 1999: Compelling ideas, Investigating and engaging, Support of student autonomy, and Real-World outcomes. In the other project the students devised a laboratory experiment, demonstration or game. This included the concept of working as a team to get results. "Project Based Learning can give students a richer, more "authentic" learning experience than other learning modes because it occurs in a social context where interdependence and cooperation are crucial for getting things done" (B.I.E. 1999).

III. Demographics

The Wyandotte City School District is located approximately 15 miles south of Detroit, on the Detroit River. The city covers 5.54 square miles and has a population of 28,006. During the 2001-2002 school year the high school had 1,294 students in ninth through twelfth grade. The majority of students are Caucasian.

I teach earth science and physics. The physics students are almost all twelfth grade students. Physics is an elective science class, so enrollment varies from year to year. The time allotted for each class period is 54 minutes. The class meets five days a week.

The current study, during the 2001-2002 school year, included three sections of physics. There were 70 students involved in this research project. Female students comprised 40% of the students and 60% of the students were male. All of the students were seniors except one. The mathematic background of the students varied from Algebra II through Calculus.

IMPLEMENTATION

I. Overview

Overall, the goal of this unit was to allow all students, regardless of mathematical ability, to learn physics concepts and how they relate to real-life experiences. The school year did not begin with this unit. I took a few weeks at the beginning to introduce some basic skills needed for physics, such as estimation, error analysis, and metric review. To start out the unit, I gave the students a pre-test on the topics that would be covered. After taking the pretest, some basic wave concepts were introduced. Succeeding chapters began with a qualitative activity, such as a discovery activity or a demo. Mathematics related to the concept were introduced, then the project or discovery activity to match the chapter was completed. In some cases, projects included ideas from more than one chapter. Assessment included homework, tests, and lab reports. At the end of the unit, the Pretest was used as a Posttest, and a survey was taken by the students for their input regarding this unit. The entire unit took ten weeks and included six chapters from our textbook. This unit was designed with the Michigan Objectives for Creating New Scientific Knowledge, and Physical Science Waves and Vibrations in mind. Specific objectives for this unit are discussed later

II. LON-CAPA

Along with rewriting the unit on the physics of waves using project-based physics, I also began to incorporate LON-CAPA in this unit. LON-CAPA stands for "The Learning*Online* Network with CAPA". The CAPA in LON-CAPA stands for "Computer Assisted Personalized Assignment". LON-CAPA is a computer-based delivery system that was developed at Michigan State University to allow students to study chapters and complete individualized homework online. LON-CAPA combined two previously used programs: Lecture*Online*, which is a content delivery system and CAPA, which is an individualized online homework system. The result of this union LON-CAPA is an online instructional aid that has both content pages as well as individualized homework. I became involved in this project part of the Research in Education for Teachers program run by the LITE Lab (Laboratory for Instructional Technology in Education) with Funding from the National Science Foundation. I began writing web pages of content and programming mathematical problems for the unit on the physics of waves during my summer research. Samples of content pages and problem pages can be found in Appendix G. Under the guidance of Gerd Kortemeyer, Hong-Kie Ng and Felicia Berryman, the experts at Michigan State, I learned how to program physics problems and web pages. That same summer, Michigan State University provided my school with a server to accommodate computer space needed to run LON-CAPA locally. I also received two computers for my classroom from Michigan State to make it easier for the students to complete their homework. Due to the length of time it took me to write the content and problem pages, I was not able to write these for the entire unit. However, I did construct content and problem pages for the first two chapters of the unit: wave basics and sound. LON-CAPA is cross institutional, which means not only could I write my own content pages and problems, but also I was welcome to search the LON-CAPA library and use any pages I found. This was a wonderful way to allow the students to see applets and other computer simulations pertinent to the topic they were studying that were beyond my computer expertise. I also programmed pages with examples of equations related to sound and some background information for the musical instrument project to which the students could refer online. While the library of problems from college physics classes was a bit too advanced for my students, I took advantage of the content pages. For the wave basics and sound chapters I had the students complete individualized homework that I had designed and programmed from LON-CAPA.

Ideally, the students took notes in class while I was lecturing and then went on line to review, go through the web pages for each chapter and complete the homework problems. When designing and programming problems for LON-CAPA, the programmer has the freedom to give the students as many tries to answer a problem as desired, so students could try a problem over and over with immediate feedback to correct and incorrect responses each time. I gave students ten tries for each problem, so that most students were able to get 100% on this homework. Students who did not get 100% either gave up on the problems, or did not complete the problems in the time allotted.

III. Basic Outline

Many of the activities in this unit, while not brand new, have been revised and adapted. However, the projects are new and resulted from my summer research class at Michigan State University. Many of the notes and equations for the sound portion of waves were posted on my LON-CAPA web pages as a supplement to the textbook. Two of the chapters also had homework through the LON-CAPA network. The unit including the revised laboratory experiments including the type of experiment and homework are shown on Table 1. The appendix where the activity can be found and the category of activity are also included.

Table 1: Unit outline

Activity	Appendix	Category
Pretest	E	
Wave Basics		
The Great Pendulum Race (revised)	A	Discovery Project
Grandfather Clock Laboratory Experiment	B	Experiment
Properties of waves with Slinkys	B	Discovery Activity
Sound		
Spoons on strings	B	Discovery Activity
Mach One Experiment	B	Experiment
Make a Musical Instrument	A	Discovery Project
Light		
Marshmallows and the speed of light	B	Discovery Activity
Color		
Color Observations – An Introduction (revised)	A	Experiment
"Paint by the Numbers" Colored Pigment Experiment	B	Experiment
Reflection/Refraction		
Mirror Survey	A	Discovery Activity
"The Angle on Refraction"	B	Experiment
"It's All Done with Mirrors"	A	Experiment
Lenses		
Pinhole Camera with Coffee Cans	B	Experiment
"Lab-a-thon"	A	Project
Post test	E	
Student Survey	F	

IV Objectives

Students in our school take Physics as the final class in the science sequence. As a result, all of the students in my class already have been taught most of the goals and benchmarks in the *Michigan Curriculum Frameworks* (2000). Physics class takes many of those topics to a deeper level of understanding. In our school district, physical science is first taught in the eighth grade, explored somewhat further in the ninth grade Earth Science class and studied again in eleventh grade Chemistry. While no class provided a total coverage of all of physical science, many skills were taught over and over, more in-depth each time. By the time students are in Physics, they are adept at basic lab skills, such as measuring, observation, and describing. Using these skills as a starting point, the labs and projects they devised and performed deepened these skills. Measuring skills included error analysis; describing skills included using data in explanations and relation to concepts. Laboratory reports for the projects were complex, written as formal papers, complete with abstracts, analysis, interpretation, data and conclusions. The guideline for this style of report was included in the instructions for the projects, and shown in Appendix A. Extended use of open-ended discovery activities and experiments allowed the students to prepare for the challenge of creating their own musical instruments, demonstrations, games and labs. This unit was designed to comply with the following *Michigan Curriculum Frameworks* (2000) goals and benchmarks:

- Constructing New Scientific Knowledge (C)
  I.1.1; I.1.2; I.1.4; I.1.5
- Reflecting on Scientific Knowledge (R)
  II.1.1;II.1.2; II.1.3
- Waves and Vibrations
  IV.4.1; IV.4.2; IV.4.3; IV.4.4

Table 2 shows the activities for each topic and the corresponding objectives:

Table 2: Activities and Corresponding Goals

Activity	Goal
Wave Basics	
The Great Pendulum Race (revised)	I.1.1; I.1.2; IV.4.3
Grandfather Clock Laboratory Experiment	I.1.1; I.1.3; IV.4.3
Properties of waves with Slinkys	IV.4.3; IV.4.4
Sound	
Spoons on strings	IV.4.1
Mach One Laboratory Experiment	I.1.1; I.1.3; I.1.4, IV.4.1
Make a Musical Instrument (Appendix A)	I.1.1; I.1.2; I.1.4; II.1.1; II.1.3; IV.4.1: IV.4.4
Light	
Marshmallows and the speed of light	IV.4.3, IV.4.4
Color	
Color Observations – An Introduction (revised)	I.1.1; I.1.2; II.1.2; IV.4.2; IV.4.3
"Paint by the Numbers" Colored Pigment Experiment	I.1.1, IV.4.2
Reflection/Refraction	
Mirror Survey	II.2.2; IV.4.3;
"The Angle on Refraction"	I.1.1; I.1.5; IV.4.3
"It's All Done with Mirrors"	II.2.2; IV.4.3
Lenses	
Pinhole Camera with Coffee Cans	I.1.1; I.1.2; I.1.5; II.2.1; IV.4.3
"Lab-a-thon"	I.1.1; I.1.2; I.1.4; I.1.5; I.1.1; II.1.3; IV.4.2; IV.4.3; IV.4.4

V. Laboratory Descriptions and Analysis

Many of the activities, experiments and guidelines for demonstrations are located in Appendix A. Included are experiments and/or activities I have designed or radically modified (references are included). Listed in Appendix B are experiments I use as found from other resources such as laboratory manuals and other teachers. Some activities are done as class participation demonstrations, and have no formal instructions or reports.

Students worked with a partner in most experiments and activities. Each student made their own musical instrument and worked in teams of up to four students for the "Lab-a-thon". Each student was responsible for their own laboratory report in all experiments and activities except the "Lab-a-thon".

Wave Basics

The Great Pendulum Race (Appendix A) is the discovery project that starts this section. Students use materials found in the lab to create a pendulum with a period of exactly one second. They are given a few guidelines such as "keep good records" and "do not use your fingers to release the pendulum" but the rest is up to the lab team. All groups were successful in creating a pendulum with a period of exactly one second. 74% of the students got a perfect score of 11 on their laboratory reports, and 23% got a score of 10 on their laboratory reports. The students who scored lower than ten had errors of omission such as incomplete answers or skipping questions entirely.

The Grandfather Clock Laboratory Experiment (Appendix B) is the first experiment for this unit. After students discover that the only effect for the period of a pendulum is length of the pendulum, this lab takes the idea one step further and gives a mathematical relationship between length of a pendulum and its period. This laboratory experiment provides the students with an opportunity to use and manipulate a graphing program on the computer, to create a linear relationship between the two variables used in graphing. I used this lab as is from the Conceptual Physics Laboratory Manual and guided the students through the use of the graphing program. The students performed well on this experiment; the average score was 89%. The lowest score was 14 points out of a possible

21, or 67%. Errors of omission, such as incomplete data or unanswered questions were the reason for low scores.

Properties of Waves with a Slinky™ (Appendix B) is a classroom demonstration activity without anything in writing that students submit for a grade. Every group of four students has a Slinky with which to experiment. The students are guided through the various types of waves, and experiment physically with concepts they will encounter mathematically such as the relationship between frequency and wavelength, and standing waves.

Sound

Spoons on Strings (Appendix B) is another crowd-pleasing demonstration, again without anything in written to submit. This is a very simple and effective demonstration. Two strings each about 0.5 meters long are attached to the handle of a tablespoon and given to a student. The student wraps a string around each index finger and hits the spoon on the table. Then the student puts his index fingers in his ear and hits the table again. The sound made in each method is compared. Students are impressed by the difference in sound of the two methods. Finally, another student covers their ears, and the student holding the spoon hits it on the table. Of course, the student with their fingers in their ears cannot hear the sound, so that sets up a discussion of wave damping. Students are generally surprised at the difference in tone, loudness and quality of sound when they have their fingers in their ears.

Mach One (Appendix B) This experiment is taken out of the Conceptual Physics Laboratory Manual as well. This experiment is used to demonstrate the speed of sound in air using the concept of resonance. In this experiment students use one-liter graduated cylinders, resonance tubes, and tuning forks to determine the speed of sound in air. This is a good introduction to the type of calculations they will use when creating their own instruments. Students performed well, the average grade on this experiment was 87% or 13 out of a possible 15 points. Students who did not get 15 out of 15 points made calculation errors.

<u>Behind the Music-Making Your Own Musical Instrument</u> (Appendix A) This was the big individual project of this unit. The students were able to construct an instrument that made music by using strings, bars or pipes. Of the 66 students who constructed instruments, the majority, 38 students or 58%, chose to use pipes, such as panpipes, sliding pipes (trombone-like instruments), recorders, flutes and even one bagpipe. Next in popularity were stringed instruments. Twenty students or 30% chose to construct instruments with strings, such as guitars, banjos, and dulcimers. The remaining 8 students or 12% constructed instruments with bars. Xylophones and chimes were the leaders, with one student using eating and garden utensils! Each student wrote their own formal laboratory report, including an abstract, data chart, analysis and discussion. The details of information included in the report are outlined in the copy of the project in Appendix A. For the analysis the students had to not only explain the physics behind their instruments, but also perform calculations showing the speed of sound in them. For the stringed instruments, the students determined the speed of sound on the strings, for the pipes, the speed of sound in air and for the bars, the speed of sound traveling through the bars. One common error made by students who constructed chimes or xylophone-type instruments was to consider their instruments as pipes rather than bars. Even though the students used PVC pipe or copper pipe to make the chimes or xylophone-type

instruments, they were considered bars because they were struck with an object rather than being blown into like flutes or panpipes. The calculations for bar instruments were more complex, using Young's modulus, an equation not typically presented to high school students. The average score on the instrument project was 85% or 59.4 out of 70 possible points. The most common errors in this project were incomplete explanations of how sound travels in the instrument constructed, and incorrect calculations in determining speed. Student comments on the success of their experiment in the discussion section of the lab included these remarks:

> "Although my instrument never worked properly, I conclude the lab to be a successful one anyway. I learned a lot about sound waves and how to make sound waves, as well as how fast they all travel through air."

> "I feel that my flute was quite a success. It was effective in producing standing waves in order to create different notes and make a pleasant sounding instrument."

> "My PVC flute sounded a lot like my real flute!"

> "I believe that the lab was a success...showing that instruments use physics properties in producing sound."

> "I was able to take everyday materials and create an instrument that could be played and even use it to play a recognizeable (sic) song."

> "Yes, my instrument works. Yes, my instrument can be heard."

> "My panpipe. ...allowed me to play the greatest song in the world 'Mary had a Little Lamb'."

> "My instrument played eight distinct notes."

> "I also learned how music is created by sound waves in different instruments."

Light

Marshmallows and the Speed of Light. (Appendix B) This is another interesting classroom demonstration, without a written assignment. This demonstration reinforces the concepts of the speed of light, and the electromagnetic spectrum. I first read about this demonstration in the journal, *The Physics Teacher*. However, there are also online resources for this demonstration, listed in Appendix B. One student covers a paper plate completely with a layer of regular sized marshmallows, placed next to each other and barely touching. The plate is then placed in a microwave that does not have a turntable. Once turned on, a standing wave is set up in the microwave, and at maximum amplitude the marshmallows begin to melt. The maximum amplitude is one-half the wavelength of the electromagnetic wave. The microwave is turned on just until the marshmallows begin to melt. Another student measures the distance between two melted spots and finds the half-wavelength distance, and another finds the frequency of the microwave (it is usually written on the back of the microwave). Using the equation $v=\lambda f$ the speed of the electromagnetic wave can be determined. When done carefully, this is very accurate.

Color

<u>Color Observations – An Introduction.</u> (Appendix A) This laboratory experiment was adapted from the book that came with my light box kits. Students learn about pigment colors from preschool on, but this is the first introduction to the colors of light. The students use color filters to combine various colors of light on a white screen. The big surprise of this experiment is that blue and yellow light make white, not the color green, as in pigments. One student summed up the general feeling by writing "yellow and blue I expected to be green because with crayons or paint those are the colors you would expect to get." The students are also surprised by the colored, rather than just black, shadows that appear. In this experiment the students wrote down predictions, observations, and

some explanations of their observations. The average score on this experiment was 96% or 14.4 out of 15 points.

Paint by the Numbers. (Appendix B) This experiment allows students to mix color pigments by using paints. I use this experiment as designed by Matthew Tuckey, a science teacher in Bad Axe, Michigan. Like the colored light experiment, this activity is qualitative and requires no mathematics. Students use and combine different color paints to study color subtraction. The class average was 99% or 10.9 out of a possible 11 points. The few errors that were made were errors of omission, such as not answering a question or finish painting.

Reflection/Refraction

Mirror Survey. (Appendix A) The Mirror Survey is a take-home discovery activity that introduces reflection. It addresses the concept that the image we see on a mirror appears to come from behind the mirror. Even after the survey is taken and discussed, students are still skeptical; refusing to believe the image in the mirror is not on the mirror itself. In order to prove this, I have one student stand at arm's length from the mirror and draw a circle on the mirror around the reflection of his face with an overhead marker. When the circle comes out to be half the size of his face, discussion gets lively. This discovery activity interests the students in the topic of reflection.

The Angle on Refraction. (Appendix B) Snell's Law is the basis for this experiment in which the students derive the law for themselves using the optical light boxes. The write up for this experiment is from the book that comes with the Arbor Scientific light boxes used in physics class. I use it almost as is. The students use a semi-circular, transparent Plexiglas slab and a thin beam of light. The light is shone through the slab at different angles and lines are drawn indicating which are the lines of incidence and which are the lines of refraction. The equation for Snell's law is derived from the students' data, as is the index of refraction for light going from air through plastic. If a laboratory team is careful, results are very good. The average score on this experiment was 89% or 19 out of a possible 21 points. Even if the data were not perfect, the students did not lose credit if they could explain the results.

It's All Done with Mirrors. (Appendix A) Reflection in curved mirrors is the focus of this experiment. This experiment was revised from the book that came with my optical light boxes. In this qualitative experiment, the students compared spherical and parabolic mirrors. The properties of curved mirrors were studied to promote understanding of concepts such as center of curvature and focal point. This experiment was qualitative, and the students wrote down and answered questions about their observations. The average score was 89% or 18.75 out of a possible 21 points.

Lenses

Pinhole Camera with Coffee Cans. (Appendix B) This experiment introduces lens properties to the students. I use this experiment as written by Mr. Mark Davids, a physics teacher at Grosse Pointe South High School. Using a light source and a coffee can with a small hole punched in the bottom; a real image can be formed on the plastic top of the can. Usually the students use geometry to determine the image and distance formula for lenses, but due to time constraints, the students performed the qualitative portion of the experiment and we did the quantitative portion together. All students received points for participation.

"Lab-a-thon". (Appendix A). In the final project for the unit, students worked in teams of two, three or four to devise or find and rewrite a demonstration, experiment or game for a concept from this unit. The experiments, demonstrations and games were set up and the entire class did each activity. Along with developing the procedure and experiment, each team had to have a worksheet for the other students to complete. The team then collected and graded the worksheets. One laboratory report was required per group. The average team score on this project was 90% or 31.5 out of a possible 35 points.

VI. Assessment of Unit

Various instruments were used to assess student progress during this unit. Homework included LON-CAPA questions, bookwork, and handouts. Pre and post tests were administered to determine overall retention of wave concepts, and laboratory reports were written for all experiments. A test was given for each chapter as well. At the end of the unit the students completed a survey giving me their opinions on the effectiveness of the physics of waves unit.

Pre and Post Tests

The pre and post tests were the same instrument. The test consisted of seven short answer questions. The test and scoring rubric are shown in Appendix E. The questions were conceptual in nature and designed to incorporate the material learned from this unit. The goals of the pre and post tests were to see what prior knowledge of the physics of waves the students had and chart their improvement after the unit was complete.

Homework

The homework in the unit on the physics of waves was varied. The students completed individualized problems found on LON-CAPA for the first two chapters. Along with the

LON-CAPA problems in the first two chapters as well as the rest of the chapters in this unit, the students completed questions from the book known as "Think and Explain" questions. These are conceptual questions pertinent to the chapter. These questions require a short answer. Additional mathematical problems were given via handouts. Scoring for these questions and problems are graded on participation level; students were expected to try to answer these questions. Generally, the class discussed the homework on the due date. Of course, I was always available to answer individual questions before the due date.

Laboratory Reports

There were two types of laboratory reports that the students completed. For the activities and experiments the reports were completed on preprinted forms. Except for the chapter on color and the mirror survey that were conceptual only, there were both conceptual and mathematical questions regarding the experiment. The laboratory reports for the projects were complex, requiring a formal write up. The students had to write an abstract, data section, analysis of the physics used in the project, error analysis, and discussion section.

Chapter Tests

At the end of each chapter students took a test covering the physics concepts studied in that chapter. The tests included multiple choice questions and either mathematical problems or short-answer questions.

Survey

At the end of the physics of waves unit, the students, giving me their assessment of this unit, took a survey. The survey is shown in Appendix F. There were eight sliding scale questions and three short-answer questions

EVALUATION

I. Overview

The success of this unit was evaluated using reports from experiments and projects, chapter test results, pre and post test results and a student survey.

The averages for the experiment and project results are shown along with the descriptions of each experiment and project (see also Implementation). Grading Rubrics for the projects are included in Appendix A. I have chosen to break down by letter grade the results of the projects. The grades show that students can work either on their own or in teams to solve problems and explain concepts.

Test results for each chapter as well as the results for the pre and post tests help show the retention of concepts introduced in this unit. These tests are found in Appendix C. Grading rubrics used for the tests are shown in Appendix D. The pre and post tests are the same, and were short answer, not multiple choice. A copy of the pre and post test and the grading rubric can be found in Appendix E.

Finally, the students completed a survey at the end of this unit. A copy of the student survey is in Appendix F. There were eight questions answered on a sliding scale and three short answer questions. The survey was intended to be a qualitative way to get feedback on the unit.

The grading scale I used for the tests and assignments is shown in the table below:

Table 3: Grading Scale for all assignments

Grade	Range (%)	Grade	Range (%)
A+	100	C+	77-79
A	94-99	C	74-76
A-	90-93	C-	70-73
B+	87-89	D+	67-69
B	84-88	D	64-66
B-	80-83	D-	60-63
		E	59 or less

Graphs reflect the letter grades A, B, C, D and E. Graph columns for the letter grade reflect the entire range of that grade.

II. Projects

The Great Pendulum Race (Appendix A) was the first project. As it was the introductory project the concepts were, for the most part, review from previous physical science classes. All students earned an "A" on this project. Fifty-two students had a perfect score of 11 out of a possible 11 points, and 16 students earned 10 points. The goal of this project was to familiarize the students with the procedures necessary to complete a successful project, focusing on collection and explanation of data.

Behind the Music – Making Your Own Musical Instrument (Appendix A) was the large individual project for this unit. Not only did the students have to invent or find instructions for a musical instrument, they had to explain the physics of sound behind their instrument and be able to play six different notes as well as a recognizable song. A breakdown of the grades students earned is shown below:

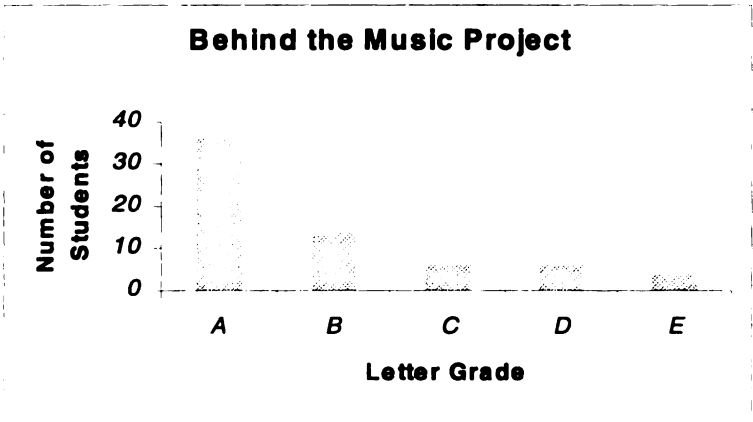


Figure 1: Grade distribution for "Behind the Music – Making your own Musical Instrument"

Thirty-six students earned an "A" on this project. In order to receive that grade, the student had to make a working instrument, play six different notes, play a recognizable tune for the class, explain the physics of sound in their instruments, complete calculations showing the speed of sound with regard to their instrument and complete discussion questions about the physics of sound found in the laboratory handout. Students receiving a "B", "C" or "D" had working instruments, but the rest of the lab was not up to par. The four students who earned an "E" were not able to construct a working instrument, and/or had very poor project reports. Four students in the class did not complete the project at all, and earned no grade.

"Lab-a-thon " (Appendix A) team project was the last project for this unit. Each team drew a slip of paper from a beaker with a lab concept we have studied – either reflection, refraction or lenses, and had to devise a demonstration, game, or experiment. Only one project report was required from each team. The grades were high, because the best writer on each team was elected by the team to write the project report. The grade distribution is shown below:

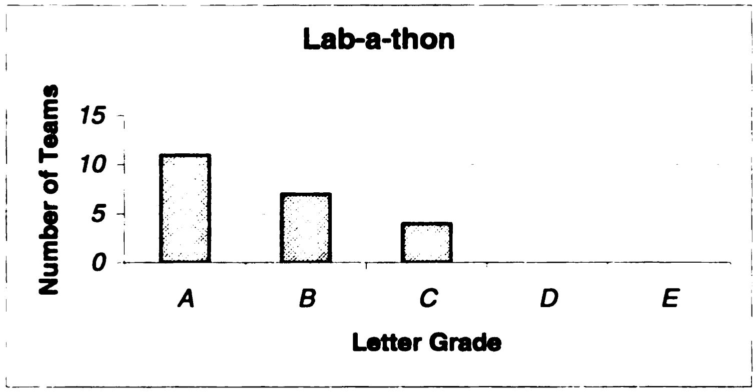


Figure 2: Grade Distribution for "Lab-a-thon" Team Project

No team earned a "D" or an "E" on this project. The teams earning an "A", described and made a demonstration, game or experiment using the concept they drew out of the beaker. The teams explained the physics of waves used in their project, gave each student a handout to complete while performing the experiment or game, or watching the demonstration, graded and handed in the worksheets and answered discussion questions. Teams earning the lower grades did not explain the physics of their experiment thoroughly, or did not turn in the other students' worksheets.

III. Chapter Tests

There were five chapter tests given with this unit. All tests consisted of both multiple choice and mathematic problems. The first test was given on wave basics. This test addressed topics such as wave types and descriptions, period of a pendulum, and the Doppler Effect. The results of this test are shown in the figure below:

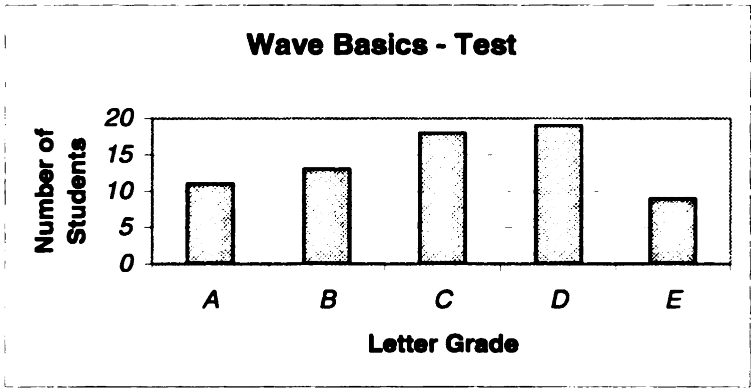


Figure 3: Wave Basics Test Results

The next chapter was the chapter on sound. Topics addressed in this chapter included the speed of sound in air and water, resonance, interference and intensity. This test incorporated information used in construction of the students' musical instruments, as well as information found on the LON-CAPA website I created. Much of the information was not found in the textbook. There were fifteen multiple-choice questions and five math problems. The grade distribution for that test is shown in Figure 4:

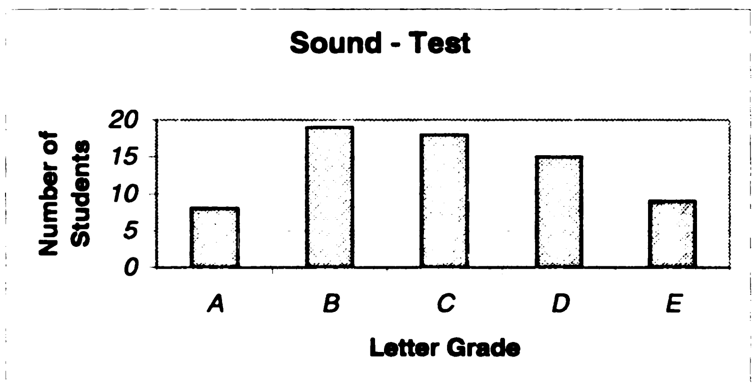


Figure 4: Sound Test Results

The third test in this unit was on light. This chapter got a short shrift due to time constraints and the students' scores are evidence of that fact. This chapter incorporates polarization, shadows, and electromagnetic waves. There were no experiments and only a few demonstrations for this chapter. The grade distribution for this short test is shown below:

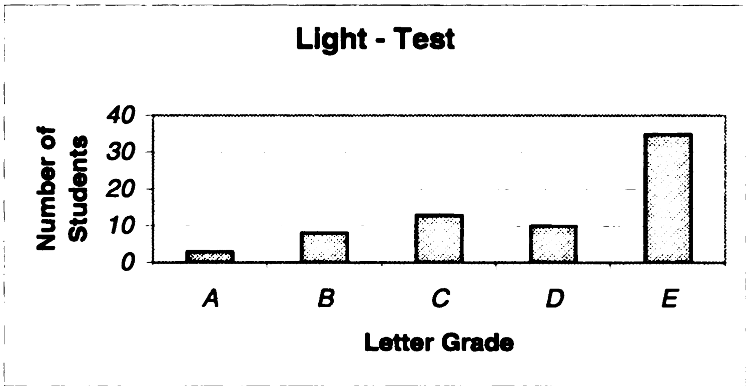


Figure 5: Light Test Results

The next test in this unit was on color. This chapter discussed complimentary colors, what causes color, color addition and color subtraction. This is a popular chapter with the students, who are quite tired of math by this time! This test is different than the rest of the tests in this unit because there are short answer questions included. The results for this test are shown in Figure 6:

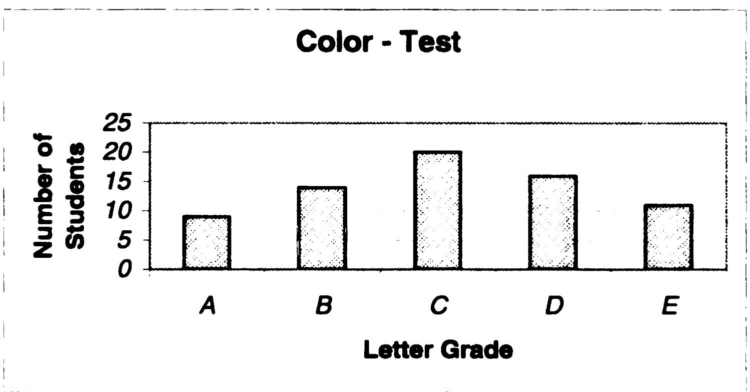


Figure 6: Color Test Results

The last test in this unit actually incorporated two chapters into one test. Again due to time constraints, the chapter on reflection and refraction had to be included along with the chapter on lenses into one test. This test included the topics of reflection, refraction and lenses. Also incorporated was the information from the students' projects as well as three experiments. Figure 7 details the results for this test.

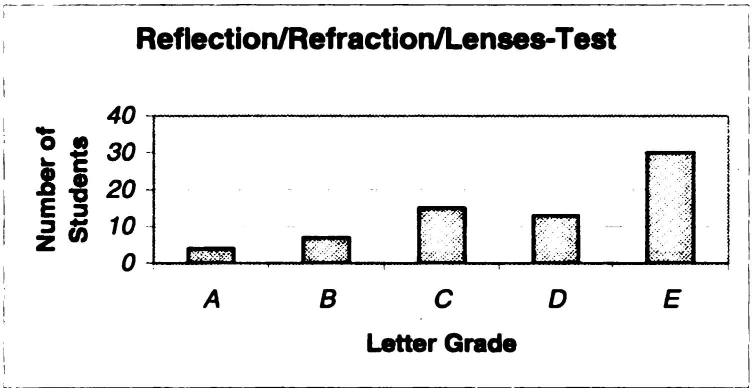


Figure 7: Reflection/Refraction/Lenses Test Results

IV. Pre and Post Tests

The same test was given before the unit started and after the end of the unit. The test included seven short-answer questions. The test was worth thirteen points. Table 3 shows a breakdown of number points vs. the number of students achieving each score. The percent of students achieving each score is also shown.

Table 4. Pre and Post Test Values

POINTS EARNED	PRETEST		POSTTEST	
	Number of Students	Percent of Students	Number of Students	Percent of Students
0	5	8	0	0
1	16	25	0	0
2	14	21	0	0
3	12	18	1	2
4	11	17	6	9
5	4	6	7	11
6	0	0	8	12
7	3	5	14	22
8	0	0	8	12
9	0	0	13	20
10	0	0	6	9
11	0	0	2	3
12	0	0	0	0
13	0	0	0	0

A total of 65 students took both the pre and post tests. The average score on the pretest was 2.5 points out of a possible 13 or 19.2 %. The average score on the posttest was 7.3 points out of a possible 13 or 56.1 %. The average improvement was 36.9 %.

V. Student Survey

At the completion of this unit, I asked the students to complete a survey, giving their opinions on this unit in two formats. The first part of the survey was a sliding scale

1 to 5, with the number 1 meaning "strongly agree" and number 5 meaning "strongly disagree". The second part of the survey contained three short answer questions. Table 4 shows the percentage breakdown of the answers to the first eight questions on the survey.

Table 5: Survey Results by Percent

Question Number	Percent of students responding					
	1 (Strongly Agree)	**2 (Somewhat Agree)**	**3 (Feel Neutral)**	**4 (Somewhat Disagree)**	**5 (Strongly Disagree)**	**No Answer Given**
1	24.6	40.0	18.5	9.2	7.7	0
2	27.7	35.4	12.3	15.4	9.2	0
3	24.6	24.6	26.2	12.3	12.3	0
4	29.2	24.6	21.6	15.4	9.2	0
5	21.6	29.2	21.6	26.2	1.4	0
6	20.0	15.4	21.6	13.8	29.2	0
7	12.3	41.5	29.2	13.8	3.1	0
8	9.2	26.2	30.8	21.6	7.7	4.5

There were two statements that brought the largest "strongly agree" response. 1) "The lab-a-thon was useful in explaining reflections and refraction"; 29.2% of the students answered "strongly agree". 2) "Constructing my own musical instrument was useful in helping to understand how sound travels" garnered a "strongly agree" rating from 27.7% of the students. The statement that brought the largest "strongly disagree" response was "I preferred the math-style homework over the Think and Explain questions", with 29.2% of the students giving a "strongly disagree" answer. Only 9.2% of the students strongly agreed with the statement "The use of the computer made the material easier to understand", this could be due to the fact we only used LON-CAPA for the first two chapters of the unit. The response to the statement "What I learned exceeded my expectations at the beginning of this unit" was heartening. "Strongly agree" earned a 12.3% response and "Somewhat agree" earned a 41.5 % response. This means that over one-half of the class, 53.8%, learned more than they thought they would. Another 29.2% learned about what they thought they would. The "disagree" statements showed that 16.9% of the students learned less than they thought they would. Of that 16.9% only two students, or 3.1% strongly disagreed with that statement. Combining the positive statements shows even more heartening information. A total of 64.6% of the students somewhat and strongly agree that this unit helped them understand how instruments with string make music. A total of 63.1% of the students agreed that constructing their own instruments was useful in understanding how sound travels. Over half of the students, 53.8%, felt that the lab-a-thon was useful in explaining reflection and refraction. One interesting fact is how the students feel about the use of math. 35.4% of the students agree that they prefer math to conceptual questions, and 43.0% of the students prefer conceptual questions to math. This fact is further reflected in the short answer questions on the survey.

There were three questions in the survey. The first question was "Which part of this unit did you like best and why?" Eighteen of the 62 students who completed the short answer questions replied that they like the instrument project the best. Some of the comments were:

> "The part with the musical instruments because I learned more on how they work"

"Making the instruments. You do not get a fun project that teaches a good lesson very frequently."

I liked making instruments, I still have mine and play it a lot."

The "Lab-a-thon" was the favorite of eleven students. A related favorite, with twelve votes was reflection/refraction. Some of the student comments were:

"The reflection and refraction section because it had things that I would never guessed about mirrors."

"...instead of everyone doing the same lab for every unit, everyone got to make their own and be creative. It also made you understand a lot of different topics instead of just one."

"I liked making our own labs.... It allowed some creative thinking and you usually understand something well when you have to teach someone else."

Another popular topic was color. Ten students picked color as their favorite topic. A typical comment regarding the color chapter was:

"I liked colors best. It was cool to find out paint and light mix differently."

Students differed more when asked what they liked the least. Eleven of the students said that they did not like the math, and that eliminating math problems would have helped. As one student stated " I did not like the math equations because they were boring." The following topics: waves, lenses, instruments, color, reflection/refraction, tests and the "Lab-a-thon" each had four or five "least favorite" ratings. When asked "What do you think would have helped you understand this unit better?" the most frequent answer (eleven students) was student related. Some typical comments were:

"If I tried harder."

"Coming to class earlier."

"...paying more attention would have helped me understand it more. That is all I truly needed to do."

Other popular suggestions included spending more time on each topic, doing more hands-on activities and more demos. One student suggested I change the way I teach. However five students said that there was nothing that could have been done to improve the unit, that it was understandable and well presented.

DISCUSSION

I. Evaluation

This unit was successful in helping students learn through the use of projects. All students were able to create a pendulum with a period of exactly one second. This mini-project was a nice launch into the unit. One student cited making a pendulum as the part of the unit he liked best.

Almost all students were able to construct and play their own instruments, using common household materials and without using parts of existing instruments. The students explained the physics of waves behind their instruments in a formal laboratory report. The drawback to the instrument project is that as the instruments became more complicated, so did the physics involved. Instruments with strings, panpipes and trombone style instruments proved to be the simplest instruments to describe in terms of physics principles. The mathematical equations were also straightforward. However, instruments with bars had a more complex formula and were not as easy to explain. Flutes and recorders were complex because the students did not cover the holes all in sequence when the instrument was played. Sometimes every other hole may have been covered, which led to more complex physical explanations. There were also a few instruments that defied high school mathematics, such as the garden tool chimes and the Mylar balloon bagpipe. Overall student response to this project was positive. The students staged an impromptu jam session on the due date that was very well received.

All students were able to work in teams to develop a demonstration, game or experiment about reflection, refraction or lenses. Explaining their projects, and designing and grading worksheets gave the students opportunities to improve their communication skills and learn by teaching. Again, general student response was positive.

Less successful were the test results. I have been teaching this same unit for six years. The test scores generally follow a bell curve, like the graph shown in Figure 6, the test on Color. However, this time some of the tests showed more low scores, resulting in a skewed curve on most of the tests. The tests on the Light Chapter and the Reflection/Refraction/Lenses test showed the most failures. These tests had two factors in common. I rushed through the material in these chapters due to time constraints, leaving out a few laboratory experiments and demonstrations that I usually do. Both of these tests were also given on a Monday, a practice I usually avoid. Most disappointing were results of the test on the light chapter. However, that was the chapter with the least amount of demonstrations and experiments. In the case of the Reflection/Refraction/Lenses Test, two chapters were combined into one test. I do not do this on a regular basis. It is my opinion that there was too much of a time crunch and too much material included on this test. While I added in projects to this unit, I did not take out many of the laboratory experiments I usually have the students perform. This contributed, again, to the rushed feeling of this unit on the physics of waves.

However, the test on the Sound Chapter was quite successful. This was a high-interest chapter for the students. The curve was skewed toward the high end, with quite a few students achieving a grade of "B". This is the chapter on which we spent the most time. This chapter also had LON-CAPA web and homework pages, as well as regular experiments and a project. .

Also disappointing were the results of the pre and post tests. The retention rate of knowledge was not what I expected. Although an increase of 36.7% is a big increase, the overall average of the post test was just under 60%. (which would be a failing grade). Again, there may have been too much material to cover in too short a time. Constantly reviewing material from earlier chapters during the course of the unit would help improve those scores. Another option would be to give a mid-unit test to see how the earlier material is retained after a shorter time period. This would help me decide if there was too much content being taught in too short a time period. In the pre and post tests I did not allow for partially correct answers. The questions were either right or wrong. In retrospect, there were some answers that were partially correct that I would have given some credit for on a regular chapter test. One question asked why cowboys in the old west put their ears to train tracks to tell if a train was coming. Many students wrote that the cowboys could feel the vibrations of the train. This is a partially correct answer. The vibrations are what cause sound. However, I only graded completely correct answers as correct.

The students related, by both the surveys and verbally, that they enjoyed this unit. The large number of positive comments on the projects convinced me that this is a step in the right direction. An unexpected bonus was the students' enthusiasm for the conceptual approach to the subject. Especially in physics, which lends itself so well to math, there is a constant pull to teach a more math-based class. It is easier for the teacher, and the "right" or "wrong" answers that students crave are merely an equation away. However, the response to the conceptual aspects of this unit convinced me that the struggle to explain with words as opposed to numbers is a valid pursuit. The negative comments students made on the survey were a much smaller percentage than the positive comments and scattered over many topics. I found this encouraging, as there was no one aspect of this unit that the majority of students disliked.

Although I only used LON-CAPA for two of the chapters, wave basics and sound, I was pleased with the effect. Having students complain because now they have to do their own homework is a complaint I enjoyed hearing. The students could show each other how to complete a mathematical problem, but they could not just hand over the answers. I will be working on programming the rest of the chapters in this unit, as well as the rest of my physics curriculum on to LON-CAPA over the next year. As I have stated, writing web pages and problems for LON-CAPA is very time consuming. However, once the pages and problems are written they are there for use for as long as I want them, and only require updating as dictated by the curriculum. Also, we had various server, provider and virus problems this year that made implementation of LON-CAPA difficult. These problems have been addressed, so I look forward to improved performance of LON-CAPA in the coming years.

II. Improvements

Of glaring importance in the improvement category are the tests. The test difficulty will have to be designed to be proportional to the amount of time spent on the chapter. I can institute some mid-chapter quizzes to check the progress of the students in that particular chapter. Due to time constraints I did not do as many demonstrations as I usually do for this unit. I believe I need to find the time to put those back in to help foster student understanding. I also will review and revisit wave basics throughout this unit to help with retention. When I implement the instrument project next time, I will only allow simple instruments. There are enough variations of basic pipe and string instruments to provide variety. I also need to learn more about music myself! The school band director was my constant source of information during this project. Students who had more complicated instruments were frustrated trying to figure out the wave patterns and speed of sound for those instruments. We never did find a suitable equation for sound in a bagpipe! Another improvement I wish to make is the utilization of LON-CAPA for reference and homework. The test scores would be better if the students understood how to do the problems. I noticed a large number of "similar answers" on the homework students turned in. Unfortunately, many of them were incorrect answers. The two chapters I had set up on the LON-CAPA network provided students with a great reference source, as the students who actually went on line and looked at them agreed. As for the time constraints – I believe that will always be a problem for teachers. We are trying to condense 6,000 years of science into 40 weeks and it is difficult. Every time I think that I should leave a topic out, color for example, student response to that topic encourages me to leave it in. I may have to be more selective in the future.

Besides the mousetrap cars, which are a tradition, I am going to incorporate projects into some of the other topics. Projectiles lend themselves to projects such as catapults and rubber band launchers and electronics to projects such as motors.

III. Conclusion

As with any new revision of a unit, this thesis is simply the starting point. I do believe in the value of hands-on projects, discovery experiments and a conceptual approach to physics. The conceptual approach is a good way to bring physics from a high-level, honors-students-only enrollment to a wider student base. Projects such as making an instrument or designing a game bring physics into the students' world. One of the best projects in my class was a pair of "drunk goggles" that a student made out of diverging lenses. He got the idea from an assembly in which the police had a pair of glasses that students tried on to see what it was like to be drunk. In order to construct these goggles, the student had to know which type of lens would work and why. As their experiment, all the students in the class had to try and walk in these goggles, and answer some questions about diverging lenses. This project was a great example of using the understanding of physics in a real-life situation.

I must admit I enjoyed hearing the music, trying the games and experiments and watching the "thrill of victory" on the students' faces when they were successful in their endeavors. A project that brings the students real world into a school subject is good for both the student and teacher.

APPENDICES

APPENDIX A

EXPERIMENTS AND PROJECTS

NAME____________________________ DATE______________ HOUR_________

THE GREAT PENDULUM RACE - PHYSICS HP

The period of a pendulum is the time it takes to complete one cycle. One cycle is completed when a pendulum swings from a position of displacement and back to that same position. To determine the length of the period, time the pendulum for ten cycles, and divide the total time by 10. In this project you will build a pendulum with a period of exactly one second in order to discover what determines the period of a pendulum. Use the following guidelines in building your pendulum:

- Use a small angle of release (between 5 and 10 degrees)
- Use a pencil or ruler to hold you pendulum at the release point. It is too easy to give the pendulum a "push" if you fold it in your hand and release it.
- Use the scientific method! Change one variable at a time to see the effect.
- Keep good records! Observe, time and write down everything in an organized fashion.
- Have the instructor okay your design before you begin building, and witness the great one-second period after you are done!

Data: On a separate piece of paper, create a format to display all data taken in the project. Be sure to note construction changes, results of each trial, and any other information pertinent to your project.

Analysis: For each construction change, describe the effect on the period of the pendulum. Explain the reasoning behind construction decisions. Give a description of your successful pendulum. Complete with a schematic and measurements.

Discussion:

1. If you set up your pendulum atop Mt. Everest, would the period be less than, the same as, or greater than it would be in your lab? Explain.

2. If you set up the pendulum aboard an orbiting space vehicle, would the period be less than, the same as, or greater than it would be in your lab? Explain.

Reference:
Hewitt, Paul and Robinson, Paul. Conceptual Physics Laboratory Manual, Addison-Wesley Publishing, Menlo Park, CA. 1997. pgs 221-222.

THE GREAT PENDULUM RACE – GRADING RUBRIC

Successfully construct a pendulum with a period of one second	2 points
Data Table: Clear, concise, complete with construction details	2 points
Analysis: The effect on the period of the pendulum for each construction change. Reasoning behind construction decisions. Schematic of pendulum.	3 points
Discussion: Questions answered and explained using principles learned to date. Answers complete.	4 points

Behind the Music!
Build Your Own Musical Instrument

In this lab you will use the concepts learned in Chapters 25 and 26 to construct your own musical instrument. As part of your lab, you will play a song for the class. (And we may have a Physics "band" and all play the same tune.) There will also be a formal lab write-up, where you will explain how your instrument works, and the physics behind the music. Your instrument must meet the following qualifications:

- It must be free standing and complete.
- It must be portable.
- You must be able to play at least six different notes, and a recognizable song.
- You may not use any actual instrument parts (such as a mouthpiece from a trombone, or the neck of a guitar)
- You may not use a commercial kit to make your instrument.
- You must be able to clearly hear the instrument throughout the classroom.

You must use common, everyday materials in construction. You may select an instrument that uses strings, pipes or bars. I may ask to see preliminary plans a week before the due date. Keep notes as you go along and your lab report will almost write itself! This is an individual project, which means you will not have a lab partner. You will also complete your own lab report. This is a formal lab, requiring lots of detail. You must turn in two copies of your lab report. I will return one to you and keep the other.

Your lab report will consist of the following sections:
Abstract: The abstract should contain the purpose, a brief procedure, and any unusual materials used and schematic. The schematic should be labeled and contain measurements (in metric, of course). The drawing does not have to be to scale, but should be an accurate representation. Note: Write this section in paragraph form. Do **not** write subheadings and then a list under them.
Data: The data section is simply a table of measurements and derived values. This is not the place for equations or calculations. The types of data here will be the frequency and notes of your instrument, wavelengths of the notes, and other types of data you may find while working on this lab.
Analysis: This is the most important part of your lab. This is where you describe what you did, the construction decisions you made and why, and explain the physics behind the music. In your interpretation of physics, do not explain what frequency is – tell me how it applies to your lab. You will also include any calculations and formulas used in this lab. Error analysis is included in this part of the write-up as well.
Discussion: In this section you will answer any questions present in the lab. You will also discuss the accuracy and success of your lab, and identify any sources of error and uncertainty.

BEHIND THE MUSIC – GRADING RUBRIC

This assignment was worth a total of 70 points.

Instrument complete and turned in on time.	10 points
Student able to play 6 different notes on instrument	10 points
Student able to play a recognizable tune on instrument	5 points
Maximum points for project report	45 points

Rubric for project report is shown below:

Cover Page	2 points
Abstract: Written concisely with the purpose, procedure, materials and detailed schematic (with measurements in metric)	10 points
Data: Data should give numbers for frequency, length, and speed of sound the accepted frequency of each note, percent difference between experimental and accepted frequency of each note. Data should be in chart or table form	7 points
Analysis: Analysis should include all equations used in this project, all calculations, error analysis for calculations, and interpretation of physics used, including resonance, standing waves, frequency, length of string or air column. Students are to explain how these topics relate to their projects.	16 points
Discussion: In this discussion section there were two questions to answer (each worth 2 points). Worth two points each were comments and explanation of the success of the lab, accuracy of the instrument, and sources of uncertainty.	10 points

NAME______________________________ DATE__________________ HR______

COLOR OBSERVATIONS
AN INTRODUCTION TO COLORS OF LIGHT

As children, we learn about colors by painting and drawing. This lab will focus on your knowledge of the nature of colored light. Have fun!

Materials:

light box and power supply
screen
six transparent color filters
six solid color cards
small object

Part One

For this part of the experiment you will use the red, green and violet cards and filters. Line the three cards side by side against the screen. Using the end of the light box fitted for holding filters; insert one of the filters into the end of the box. Record the observed colors of the cards when illuminated by the different colors of light in the table below.

Color of Card in White Light	**Color of Card when Incident Light on the Card is:**		
	Red	**Green**	**Violet**
Red			
Green			
Violet			

Were you surprised by the results of this experiment? Explain.

What is the explanation for the colors that you observed when the cards were illuminated by the different color filters?

Select three other cards, and any three filters. Write the names of the colors in the table below. Perform the experiment again, first predicting what colors you will see, and then writing the colors you see.

Color of Card in White Light	**Color of Card when Incident Light on the Card is:**					
	Predicted	**Actual**	**Predicted**	**Actual**	**Predicted**	**Actual**

Did your results match your predictions? Explain why or why not.

Part Two – Addition of Colors

Using the side positions, together with the end of the light box, project three colored beams on to the screen. Use the colors blue, red and yellow. (NOTE: Place the weakest color in the end position of the light box and the stronger colors at the sides. This compensates for loss of intensity during reflection from the side mirrors.) Move the mirrors to use the beams to overlap and record your observations below.

RED + BLUE gives: ______________________________________

RED + YELLOW gives: ___________________________________

YELLOW + BLUE gives: __________________________________

RED + YELLOW + BLUE gives: _____________________________

Were you surprised by any of the results? Explain.

Now perform the same experiment using red, blue and green. Predict what colors you will observe and then test your prediction.

RED + GREEN	Predicted ______________________________	
	Actual __________________________________	
RED + BLUE	Predicted ______________________________	
	Actual __________________________________	
BLUE + GREEN	Predicted ______________________________	
	Actual __________________________________	
RED + BLUE + GREEN	Predicted ______________________________	
	Actual __________________________________	

Were your predictions correct? Explain why or why not.

Using your textbook, define the term Complementary Color

Using your data from Part Two, name the complementary colors for the following:

RED ____________________________ BLUE ________________________

GREEN _________________________ YELLOW _____________________

What color would you add to magenta to make white light? Explain.

What color would you add to cyan (turquoise) to make white light? Explain.

Part Three – Shadows

Place your small object in front of the screen. Illuminate the object with red light. What color is

the shadow? ____

If you illuminate the object with blue light instead of red light what color will shadow be?

_____________________ Try changing filters and see if you are correct. ____________

If you illuminate the object with two crossed beams of light, both red and blue, what color will

the shadow be? ____ Place the object in
the path of the crossed beams and explain the shadows that you observe. (To help you explain, draw a sketch of the arrangement, including direction and color of the light and shadow(s)).

If you illuminate the object with red, blue and green light what color will the shadow be?

____ Place the object in the path of the crossed beams and explain the shadow(s) that you observe. (To help you explain, draw a sketch of the arrangement, including direction and color of the light and shadow(s)).

HERE'S LOOKING AT YOU! - MIRROR SURVEY

Suppose that you are standing 1.0 m from and directly in front of a flat mirror that is attached to a wall. As you look at the mirror **you see an image of yourself**. Answer the following questions as completely as possible.

1. Compared to your position and the position of the mirror, exactly **where** is the image?

____

2. As you move closer to the mirror, does the size of the image change? What if you move farther from the mirror?

____

3. If someone else looks towards the mirror at YOUR image, will it appear in the same place that you see it? Explain.

____

4. If you wish to see more of your image in the mirror, **what should you do?**

____

For homework, ask someone else the same questions (not another or former physics student and record their responses here: (The response that the image is inside the eye is not acceptable.)

1. ____

2. ____

3. ____

4. ____

Reference: Mr. Mark Davids, Grosse Pointe South High School, Grosse Pointe, MI

NAME ____________________________ DATE____________________ HR______

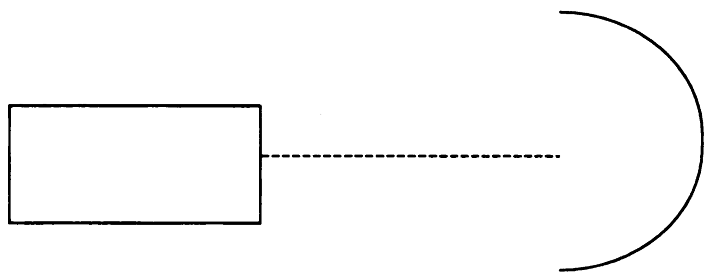
IT'S ALL DONE WITH MIRRORS!
REFLECTION IN CURVED MIRRORS

Purpose: Discover reflection properties of convex, concave, and parabolic mirrors.

Materials: Light Box, semi-circular curved mirror, parabolic mirror, slide with three light slits.

Part One:

1. Select the semi-circular curved mirror. Aim a set of parallel rays into the center of the inside curve of the mirror (making a concave mirror) so that the rays are parallel to the axis of symmetry of the mirror.



2. Draw the incident and reflected rays and note where they meet. This point is called the FOCUS of the mirror. How far is the focus (or FOCAL POINT) from the mirror?

____

This distance is called the FOCAL LENGTH of the mirror.

Part Two:

1. Set up as in part one and on paper trace the inside reflecting surface of the concave mirror. Move the mirror around the curve and continue tracing until you have a complete circle. Measure the diameter of this circle in at least five directions, and calculate an average diameter.

Show your work here:

From the diameter of the circle, please calculate the radius. What is the radius of the circle?

How does the radius of the circle compare with the focal length you found in Part One?

Part Three:

1. On another piece of paper (or at the bottom of your paper), trace the inside of the semi-circular mirror. You can use another method of finding the center of curvature. Aim a single ray at the inside curve of the mirror so that it reflects straight back on itself. To do this, the ray must be meeting the surface along its "normal" or be perpendicular to the surface at that point and must be reflected back along this radius position through the center of curvature. Record this ray position.

2. Without moving the mirror, move the ray box to another position where the ray again reflects back on itself and record the new ray position. Repeat this procedure a third time.

3. The point where the rays meet is the CENTER OF CURVATURE and the distance from this point to the curve is the RADIUS OF CURVATURE. Compare the radius to the radius you found in part two. Is there a difference? Explain.

Part Four:

1. Turn the semi-circular mirror so that the light rays strike the outside surface (this makes a convex mirror), parallel to the axis. Record the mirror position and ray paths and indicate the ray directions with arrowheads.

2. Determine where the diverging rays appear to come from by drawing the diverging (reflected) rays backward through the mirror position. The point they come from is called the VIRTUAL FOCUS and the distance of this point from the mirror is called the VIRTUAL FOCAL LENGTH. Measure this distance and record that value here:

How does the focal length compare with the focal length of the other side of the mirror?

How does the focal length compare with the radius of curvature of the mirror you found in part three?

By how much do the results differ? Please give an explanation for any difference.

Why are convex mirrors used as rear vision mirrors in cars?

Part Five:

1. Aim a set of parallel rays into a concave parabolic mirror along the paths parallel to the axis of symmetry of the mirror, just as you did with the semi-circular mirror in Part One. Record the mirror and ray patterns. What is the focal length of the mirror?

2. Move the light box sideways, keeping the rays parallel to the axis of symmetry. What do you notice about the position of the focal point?

3. Aim a broad parallel sided beam of light into the parabolic concave mirror and observe and record the effect from the light rays.

4. Predict what would happen if you used the parabolic reflector as a convex mirror. Would there be a focal point? Where would it be? Try it and see!

PREDICTION (Draw your prediction):

ACTUAL:

Discussion Questions:

1. What shaped mirror would be used to produce sharp images of stars scattered in all directions over the field of view? Explain.

2. What do you think would happen if a point source of light, such as a very bright, small light bulb (lamp) were placed at the focal point of a parabolic mirror? Explain

3. Why do radar antennae, radio telescopes and car headlamp reflectors have a parabolic shape rather than a spherical shape?

4. Please define the following terms:

    Center of curvature

    Focal point

    Focal length

    Axis of symmetry

    Radius of curvature

Reference: Experiment Handbook, Industrial Equipment and Control Pty., Ltd., Melbourne, Australia.

IMPORTANT BULLETIN!!!

E.P.L., Inc. has OVERBOUGHT! A leading manufacturer of wave equipment has gone out of business and E.P.L., Inc. has bought out the inventory. As a result, E.P.L. is looking for exciting demos, games and experiments on light, reflection, refraction and lenses. Your research team has been selected to develop a demo, game or experiment on one of the topics covered in our wave unit. The topic you will have to research will be assigned by closed bids (in other words, drawn out of a beaker). Your team may use equipment available in the classroom. If there is equipment or materials you wish to use other than what is in the classroom; you must okay it with your supervisor. (That would be Ms. Ebrahimi). Your team will have to research the topic, design a demo, game or experiment for the concept; write an explanation sheet and write questions to go with your project. You will be given some class time to work on this project.

You are welcome to research your topic on the Internet, or to ask your supervisor for advice. You must make sure your project works before you have the class try it. Your project must meet the following requirements:

1. It must be performed in the classroom.
2. It must not take longer than 10 minutes to complete.
3. You must have a handout for each student. If you give me a handout two days before the lab day I will make copies for you. If you procrastinate and do this last minute, you are on your own.
4. You must hand in a key for your questions. You are not required to perform your own experiment or game on lab-a-thon day.
5. On the due date we will have a lab-a-thon. All the projects will be set up in the classroom and everyone will try each one.
6. Ms. E. and a distinguished panel of judges (the class) will vote for their favorite project. The team with the highest score from the class will be rewarded accordingly.

Your projects do not have to be complicated, but they must make evident the principles of your topic. Your project will be graded according to the following criteria:

1. Objective and Procedures – are they clear and concise? Can your fellow students tell what objectives you are testing?
2. Does it show the objectives?
3. Questions – are the questions fair? Can the answers be found from looking at the demo, playing the game, performing the experiment or using class notes or the textbook?
4. Were you done on time?

LAB WRITE-UP GUIDELINES
LAB – A - THON

LAB DUE DATE: ______________________________

This will be a formal lab write-up. Only one report per team will be turned in. Please turn in **two** copies of your report. I will hand one back, and keep the other. Please include the following information in your report:

TITLE PAGE: The title page should include the team name (if there is one), the names of the team members, the experiment name, date, class and hour.

ABSTRACT: The abstract should contain the purpose, the concept you demonstrated, a brief description of your lab, demo, or activity, materials used and a schematic of your set up.

DATA: The data included in this lab will be the total number of students who performed your lab and a breakdown of correct and incorrect answers by your fellow students on the lab worksheets. Also please list the most common problem that was incorrect and the most common incorrect answer. Also attached to the data section should be your answer key.

ANALYSIS: In the analysis section, please tell exactly what each team member contributed to the lab. This is also where you will tell me the physics behind your lab (yes-the dreaded interpretation of physics). Explain in detail the concepts and physics behind your activity. If you used any equations or problems in your lab, list them in this section. There is no error analysis for this lab.

DISCUSSION:

1. How could you have rewritten or redone your activity to make it clearer?

2. What do you believe was the reason for the most common error that occurred?

3. Did this lab (writing and performing) help you better understand Chapters 29 and 30? Please give details.

Also in the section please comment on the success of your lab. Do you think your lab conveyed the principles intended? Please attach the lab reports to this lab when you turn it in. (You don't have to make copies of the students' papers, just turn them in.)

LAB -A – THON
CLASS VOTING BALLOT

STUDENT NAME ____ HR________

My vote for best project goes to the project titled:

My reason(s) for choosing this project as the best are as follows:

LAB-A-THON TOPICS

Law of Reflection – Plane Mirrors
(must use at least five mirrors)

Law of Reflection – Curved Mirrors
(must use at least 2 mirrors)

Refraction of Light

Total Internal Reflection

Rainbows (spectrum)

Microscopes

Telescopes (reflecting or refracting)

Converging Lenses

Diverging Lenses

Real vs. Virtual Images

Focal Length – mirrors and lenses

"LAB – A – THON"- GRADING RUBRIC

Title Page: 2 points.

Abstract: The abstract should contain the purpose, the concept you demonstrated, a brief description of your lab, demo, or activity, materials used and a schematic of your set up. 5 points

Data: The data included in this lab will be the total number of students who performed your lab and a breakdown of correct and incorrect answers by your fellow students on the lab worksheets. Also please list the most common problem that was incorrect and the most common incorrect answer. Also attached to the data section should be your answer key. 8 points

Analysis: In the analysis section, please tell exactly what each team member contributed to the lab. This is also where you will tell me the physics behind your lab (yes-the dreaded interpretation of physics). Explain in detail the concepts and physics behind your activity. If you used any equations or problems in your lab, list them in this section. There is no error analysis for this lab. 12 points

Discussion: Questions were 2 points each. Comment on the success of your lab. Do you think your lab conveyed the principles intended? 8 points

APPENDIX B

RESOURCES FOR DEMONSTRATIONS AND EXPERIMENTS

Resources for demonstrations and experiments not found in Appendix A.

Wave Basics

Grandfather Clock Laboratory Experiment: Conceptual Physics Laboratory Manual, Third Edition. Paul Robinson. Page 223

Properties of Waves with Slinkys: Hands on Physics Activities with Real Life Applications. James Cunningham and Norman Kerr. Center for Applied Research in Education. Page 357.

Sound

Spoons on Strings: Hands on Physics Activities with Real Life Applications. James Cunningham and Norman Kerr. Center for Applied Research in Education. Page 393

Mach I Experiment: Conceptual Physics Laboratory Manual, Third Edition. Paul Robinson. Page 223

Light

Marshmallows and the Speed of Light: Apopka High School http://www.bowlesphysics.com/marsh.htm *or* Alex's Fun Experiments www.geocities.com/CapeCanaveral/Runway/6095/speedoflight.html

Color

Paint by the Numbers: Mr. Matthew Tuckey, Bad Axe High School, Bad Axe Michigan

Reflection/Refraction

The Angle on Refraction Experiment: Handbook from Arbor Scientific Light Boxes. pgs 12-14.

Lenses

Pinhole Camera with Coffee Cans: Mr. Mark Davids, Grosse Pointe South High School, Grosse Pointe, MI.

APPENDIX C

CHAPTER TESTS

PHYSICS EXAM – WAVE BASICS

DO NOT WRITE ON THIS EXAM. Complete the following sections as requested.

Multiple Choice. Select the best answer for each of the following questions. Write the letter of the correct answer and your answer on your own paper. (3 points each)

1. The time needed for a wave to make one complete cycle is its
   A. frequency. C. wavelength.
   B. period. D. speed.

2. Hertz is a
   A. radio wave. C. unit of frequency.
   B. unit of period. D. unit of wavelength.

3. A wave created by shaking a rope up and down is a
   A. transverse wave. C. constructive wave.
   B. longitudinal wave. D. Doppler wave.

4. Unlike a transverse wave, a longitudinal wave has no
   A. amplitude. C. wavelength
   B. frequency. D. A longitudinal wave has all of the above.

5. Two waves arrive at the same place, at the same time, and the same direction of amplitude. Each wave has amplitude of 1 meter. The resulting wave has an amplitude of:
   A. 4 m. C. 1 m.
   B. 2 m. D. 0.5 m.

6. Where can you touch a standing wave without disturbing the wave?
   A. At a node. C. At any place along the wave.
   B. At an antinode. D. A wave is always disturbed.

7. When a sound source moves towards you what happens to the wave speed?
   A. It increases. C. It stays the same.
   B. It decreases.

8. The amplitude of a particular wave is one meter. The top-to-bottom distance of the disturbance is:
   A. 2 m. C. 0.5 m.
   B. 1 m. D. Zero.

9. If you quadruple (increase by 4 times) the frequency of a vibrating object, it's period
   A. increases by one fourth. C. decreases by one-fourth.
   B. increases by four. D. decreases to one-fourth of the original.

10. During a single period, the distance traveled by a wave is
    A. one-half wavelength. C. two wavelengths.
    B. one wavelength. D. depends on the wave.

11. What happens when an airplane is flying faster than the speed of sound?
    A. A shock wave is produced.
    B. There is no sonic boom.
    C. It becomes very quiet on the plane.
    D. The plane cannot be heard on the ground.

12. A Doppler Effect occurs when a source of sound moves
    A. towards you. C. away from you.
    B. both A and C. D. at the same speed you are moving.

13. The frequency of the second (sweep) hand on a clock is
    A. 1/60 (0.017) Hz. C. 60 Hertz.
    B. 1 Hertz. D. Zero.

14. If a pendulum clock were taken from Earth to the Moon, it would
    A. gain time. C. neither gain nor lose time.
    B. lose time.

15. A sonic boom
    A. is produced as a plane breaks the sound barrier.
    B. is produced by subsonic bullets.
    C. is swept continuously behind a plane flying faster than the speed of sound.
    D. is both A & C.

Problems. Complete the following calculations. Round your answers to two places past the decimal point (the hundredths place). You must show your work, and include proper units. Draw a box around your answer. Use 9.81 m/s^2 for gravity on Earth.

16. Ms. E's favorite radio station broadcasts at a frequency of 104.3 MHz. What is the wavelength of the radio waves from her favorite station? (3 points)

17. Gravity on Mars is 2.94 m/s^2. How long would a pendulum be that had a period of 3.78 s? (3 points)

18. A boat at anchor is rocked every 2.5s by a wave traveling at 6.4 m/s. What is the wavelength of the water waves? (3 points)

19. A microwave has a frequency of 2.45×10^9 Hz. What is the period of the microwave? (3 points)

20. Batman has lost his Batmobile in the Batcave. Luckily, he has his ultrasonic Batears to help him locate the Batmobile in the dark. If the Batears emit ultrasound at a frequency of 4.7×10^4 Hz, and the waves travel at 342.5 m/s, what is the wavelength of the waves? (3 points)

EXCITING BONUS QUESTION:

Why do waves coming from a fast boat have a smaller conical angle than waves coming from a slow boat? Explain your answer.

CHAPTER 26 – SOUND
PHYSICS EXAM

Multiple Choice. Read each question carefully, choose the best answer and write the letter for that answer, and the answer on your own paper. You may use the equation sheet of possibly helpful equations. (3 points each) Do not write on this test!

1. Sound waves are produced by
   A. radio stations
   B. vibrating objects
   C. objects under pressure
   D. soft objects

2. In which one of the following does sound travel the fastest?
   A. Steam
   B. Water
   C. Ice
   D. Sound travels at the same speed in each.

3. The phenomenon of beats results from sound
   A. refraction. B. reflection. C. interference D. all of these.

4. Compared to the threshold of hearing (0 db), a sound level of 30 db is
   A. 10 times more intense
   B. 30 times more intense
   C. 300 times more intense
   D. 1000 times more intense.

5. The speed of sound in the atmosphere depends on
   A. its frequency
   B. its wavelength
   C. the air temperature
   D. the humidity

6. Sound waves can interfere with one another so that no sound results.
   A. True B. False

7. The singer, Caruso, is said to have made a crystal chandelier shatter with his voice. This is an example of
   A. an echo. B. sound refraction C. beats. D. resonance.

8. How many times a minute will you be in step with a friend when you walk at 80 steps per minute and your friend walks at 75 steps per minute?
   A. 0 B. 5 C. 75 D. 155

9. Sound waves cannot travel in
   A. air. B. water. C. a vacuum. D. sound waves can travel in all of these.

10. When the handle of a tuning fork is held solidly against a table, the sound becomes louder and the length of time the fork vibrates
    A. becomes shorter. B. becomes longer. C. stays the same.

11. As a result of resonance

A. the wavelength of a wave increases.
B. the frequency of the wave increases.
C. the amplitude of a wave increases.
D. the speed of a wave increases.

12. Beats are produced when two tuning forks, one of frequency 240 Hz and the other one of frequency 246 Hz, are sounded together. The frequency of the beats is

A. 6 Hz B. 12 Hz. C. 240 Hz D. 486 Hz

13. Compared to a sound of 40 decibels , a sound of 60 decibels is

A. 20 times the intensity. B. 100 times the intensity. C. 200 times the intensity.

14. Resonance occurs when

A. sound makes multiple reflections.
B. sound changes speed in going from one medium to another.
C. the amplitude of a wave is amplified.
D. an object is forced to vibrate at its natural frequency.

15. Sound waves in air are a series of

A. high and low pressure regions
B. periodic disturbances
C. periodic compressions and rarefactions.
D. all of the above.

Problems. Read each question carefully. Solve. Be sure to use correct units and show your work. Please draw a box around your answer.

16. A trumpet sounds the note G (784 Hz). How many vibrations does the note make while the sound travels 38.5 meters through the air, which has a temperature of 19°C (4 points)

17. A ship is traveling in a fog, parallel to a dangerous, cliff-lined shore. The boat whistle is sounded and its echo is clearly heard 11.0 s later. If the air temperature is 10.0°C, how far is the ship from the cliff? (4 points)

18. The frequency of a tuning fork is unknown. A student uses an closed air column at 27.0°C and finds the length to be 39.2 cm when resonance occurs. What is the frequency of the tuning fork? (4 points)

19. A plane is flying at Mach 3 on a cold (-15.0°C) day. How fast in km/hr is the plane flying? (5 points)

20. A violin string that is 48.0 cm long has a fundamental frequency of 490 Hz. What is the speed of the waves on the string? (3 points)

NAME________________________________ DATE________________ HR_____

CHAPTER 27 – LIGHT - PHYSICS QUIZ

Instructions: Read each question carefully. Write the letter of the best answer in the space provided.

___________1. The color that travels fastest through clear glass is
A. red. B. green.
C. blue. D. all light travels at the same speed in clear glass.

___________ 2. Compared to air, the speed of light in water is
A. faster. B. slower. C. the same.

___________3. Which of the following waves is fundamentally different from all others?
A. Sound waves. B. Radio waves.
C. Infrared waves. D. Microwaves.

___________ 4. What is the relationship between the wavelength and frequency of a wave?
A. As wavelength increases, frequency increases.
B. As wavelength increases, frequency decreases.
C. As wavelength increases, frequency remains stable.
D. Wavelength and frequency are unrelated.

___________ 5. Compared to the velocity of radio waves, the velocity of light waves is
A. slower. B. faster. C. the same.

___________ 6. Vibrating electrons emit
A. charged particles. B. longitudinal waves.
C. energy D. alpha particles

___________ 7. The shadow produced by an object held close to a piece of paper in the sunlight would be
A. fuzzy. B. sharp and clear. C. unable to be seen.

___________ 8. If two Polaroid filters are held with their polarization axes at right angles to each other, the amount of light transmitted compared to when their axes are parallel is
A. twice as much. B. the same. C. half as much D. zero.

___________ 9. If an electron vibrates up and down 1000 times each second, it generates an electromagnetic wave having a
A. period of 1000s B. speed of 1000m/s
C. wavelength of 1000m D. frequency of 1000Hz.

__________ 10. Light travels through glass and emerges on the other side. The speed of light as it is entering the glass is __________ when it has just left the glass.

A. faster than B. slower than C. the same as
D. none, because visible light is absorbed by glass.

__________ 11. The main difference between an infrared wave and a radio is its

A. speed B. wavelength C. both A and B
D. method of propagation (transverse or longitudinal)

__________ 12. Because of absorption, a Polaroid lens will actually transmit 40% of incident nonpolarized light. Two Polaroid filters with their axes aligned will transmit

A. 0% B. 40%
C. between 40% and 100% D. between 0% and 40%

__________ 13. Ultraviolet light travels through glass by

A. setting up a resonance and using energy already in the glass.
B. energizing individual atoms.
C. ultraviolet light does not travel through glass.
D. changing to infrared waves.

__________ 14. What property of light was most important in the experiments of Roemer, Michaelson, and Galileo?

A. Light can travel in a vacuum.
B. Light can be reflected off of a mirror.
C. Light always travels at the same speed.
D. Light can be seen from a great distance.

__________ 15. Light reflects off of the car in front of you and is incident on your polarized sunglasses. The sunglasses block the light

A. traveling perpendicular to your glasses.
B. traveling parallel to your glasses.
C. traveling in any direction.

PHYSICS – CHAPTER 28 TEST - COLOR

Multiple Choice
Read each question carefully. Select the best answer for each question. Write the letter for that answer and your answer on your own paper. (3 points each)

1. Different colors of light correspond to different light
   A. velocities. B. intensities. C. polarities. D. frequencies.

2. A sheet of red paper will look black when illuminated with
   A. red light. B. cyan light. C. yellow light. D. magenta light.

3. If sunlight were green instead of white, the most comfortable color to wear on a hot day would be
   A. magenta. B. yellow. C. green. D. blue.

4. A photograph of your favorite person's yellow sweater looks ___________ on the negative.
   A. blue B. brown C. yellow D. green

5. Light shines on a pane of green glass and a pane of clear glass. The temperature will be higher in
   A. the clear glass. B. the green glass. C. neither, it will be the same in each pane.

6. The three primary colors of light addition are
   A. red, yellow and green. B. red, yellow and blue.
   C. red, green and blue. D. yellow, cyan and magenta.

7. Complementary colors are two colors that
   A. look good together. B. are next to each other on the color chart.
   C. are primary colors. D. produce white light when added together.

8. The complementary color of green is
   A. red. B. magenta. C. yellow. D. blue.

9. The sky is blue because air molecules in the sky act as tiny
   A. mirrors that reflect only blue light. B. resonators that scatter blue light.
   C. sources of white light. D. prisms.

10. The cyan color of ocean water is evidence that the water absorbs
    A. red light. B. orange light. C. cyan light. D. green light.

11. The three paint colors that are used by printers are:
A. red, green and blue. B. red, blue and yellow.
C. magenta, cyan and yellow. D. magenta, green and yellow.

12. Sunsets are red because
A. blue light from the sun is scattered by the earth's atmosphere.
B. the longest path of sunlight through the atmosphere is at sunset or sunrise.
C. red light scatters more easily in the evening.
D. there is magic in the air at sunset.

13. Magenta light is really a mixture of
A. red and blue light. B. red and cyan light.
C. red and yellow light. D. yellow and green light.

14. Colors seen on a photograph are a result of
A. color addition. B. color subtraction. C. none of these.

15. The color of an opaque object is determined by the light that is
A. transmitted. B. absorbed. C. reflected. D. both B & C.

Short Answer Questions:
Answer the following questions in complete sentences. Be sure to explain your answer completely. Please write neatly – if I can't read it, I can't grade it!

16. (3 points)Why are black and white not listed as colors?

17. (6 points)A group of students really like the shade of white that results from mixing red and cyan light. They decide to surprise their math teacher by use red and cyan paint and repainting the classroom. What color results from the red and cyan paint? Please explain why.

18. (6 points)A theatre student decides to shine a green light on a performer. The student has filters in the following colors: blue, red, yellow, cyan and magenta. How can the student make a green beam of light? Please explain thoroughly, using a "physics" explanation. You may use a diagram to help you.

EXCITING BONUS QUESTION:

If the sky on a planet in our solar system were normally orange, what color would the sunsets be? Please explain.

NAME____________________________ DATE__________________ HOUR______

PHYSICS TEST – CHAPTERS 29 & 30
REFLECTION/REFRACTION/LENSES

Multiple Choice. Read each question carefully. Select the best answer and write the letter for that answer in the space provided. (3 points each)

_____1. It is easier to see the road on a clear night than a rainy night because the road surface:
- A. absorbs more light when wet.
- B. is obscured by rain.
- C. does not get as much light due to cloud cover hiding the sun.
- D. scatters light in all directions.

_____ 2. The spectrum produced by a prism or raindrop is evidence that the average speed of light in the material depends on the light's
- A. particle nature.
- B. wave nature.
- C. color.
- D. transmission qualities.

_____ 3. Which of the following is a consequence of the refraction of light?
- A. Mirages
- B. Rainbows
- C. Internal reflection
- D. All of these

_____ 4. The critical angle for light from the bottom of a swimming pool shining upward towards the pool's surface is the angle
- A. at which light is reflected from the surface.
- B. at which all light is refracted out of the pool.
- C. where light is refracted so it just skims the pool's surface.
- D. 45 degrees.

_____ 5. A student wants to buy a mirror that will allow her to see her entire image. However, she is on a budget. What is the shortest plane mirror she can buy?
- A. A mirror that is half her height.
- B. A mirror that is equal to her height.
- C. A mirror that is twice her height.
- D. It doesn't matter what size the mirror is, as long as she stands far enough away.

_____ 6. Refraction is the result of
- A. bending.
- B. different wave speeds.
- C. more than one reflection.
- D. displaced images.

_____ 7. A beam of light emerges from air into water at an angle. The beam is bent

A. 48 degrees downward. B. away from the normal.
C. toward the normal. D. not at all.

_____ 8. A magnifying glass under water will magnify

A. more. B. less. C. the same.

_____ 9. Suppose you hold a converging lens in front of a window. An image of some distant hills focused on your hand, behind the lens. The focal point of this lens is located

A. in front of your hand.
B. behind your hand.
C. approximately at your hand.

_____ 10. If an object is located between the focal point and a converging lens, the image will be

A. larger than the object. B. upside down.
C. real. D. all of the above.

_____ 11. In drawing a lens ray diagram, one of the rays can be drawn

A. parallel to the axis.
B. through the center of the lens.
C. through the focal point of the lens.
D. all of the above.

_____ 12. Ray diagrams are used to

A. figure out what kind of lens is being used.
B. figure out where an image will be located.
C. find the focal point of the lens.
D. all of the above.

Problems. Solve the following problems. You must show your work, include units, and put your answer in the space provided.

13. A ray of light in air (n = 1.00) strikes a diamond at an angle of incidence of 20^{o}. The angle of refraction is 8^{o}. What is the index of refraction of the diamond? (3 points)

Answer to problem 13 _____________

14. What is the critical angle for light rays passing from flint glass (n = 1.61) into air? (3 points)

Answer to problem 14 ____________

15. An object 2.25 mm high is placed 8.5 cm in front of a converging lens that has a focal length of 5.5 cm.
(a) What is the location of the image? (3 points)
(b) What is the size of the image? (3 points)

Answer to problem 15a ____________

Answer to problem 15b ____________

16. A magnifying glass has a focal length of 12.0 cm. A coin, 2.0 cm in diameter is placed 3.4 cm in front of the lens.
(a) Where is the image located? (3 points)
(b) What is the diameter of the image? (3 points)

Answer to problem 16a ____________

Answer to problem 16b ____________

POSSIBLY HELPFUL EQUATIONS:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad h_i/h_o = -d_i/d_o \qquad 1/f = 1/d_o + 1/d_i$$

Ray Diagrams. Please draw the following ray diagrams using the scale shown. Be sure to answer all questions.

17. An object 32 mm high is placed 16.0 cm in front of a concave mirror with a focal length of 4.0 cm.
(a) Draw a ray diagram on a separate sheet of paper using a 1:1 scale. (3 points)
(b) According to your diagram, what is the image location? (2 points)
(c) According to your diagram, what is the size of the image? (2 points)
(d) Is the image real or virtual? (1 point)

Answer to problem 17b ____________

Answer to problem 17c ____________

Answer to problem 17d ____________

18. An object 9.0 cm high is placed 90.0 cm in front of a converging lens with a focal length of 36.0 cm.
(a) Draw a ray diagram on a separate sheet of paper using a 1:9 scale.(3 points)
(b) According to your diagram, what is the image location? (2 points)
(c) According to your diagram, what is the size of the image? (2 points)
(d) Is the image real or virtual? (1 point)

Answer to problem 18b ____________

Answer to problem 18c ____________

Answer to problem 18d ____________

APPENDIX D

GRADING RUBRICS FOR
CHAPTER TESTS

GRADING RUBRICS FOR CHAPTER TESTS

Wave Basics – 60 points total

Multiple Choice questions – 3 points each	45 points
Math questions – 3 points each	15 points
subtract 1 point for incorrect or missing units	
subtract 1 point for omitting work	
subtract up to 2 points for incorrect answer	
Exciting Bonus question answered and explained	3 points
1 point for trying – even if answer is incorrect	

Sound – 65 points total

Multiple Choice questions – 3 points each	45 points
Math questions	20 points
subtract 1 point for incorrect or missing units	
subtract 1 point for omitting work	
subtract up to 2 points for incorrect answer on each equation in the problem	

Light – 45 points total

Multiple Choice questions – 3 points each	45 points

Color – 60 points total

Multiple Choice questions – 3 points each	45 points
Short Answer Questions	15 points
#16 – 3 points, #17 – 6 points, #18 – 6 points	
In order to get all points for the short answer questions the answers should be complete and include all the physics principles pertinent to the question. Point value varies with complexity of the problem. Partial credit is given for incomplete or sub par explanations.	
Exciting Bonus Question	3 points
1 point for trying question, credit varies with quality of explanation.	

Reflection/Refraction/Lenses – 70 points total

Multiple Choice – 3 points each (#1 –12)	36 points
Math Problems (#13-16)	18 points
subtract 1 point for incorrect or missing units	
subtract 1 point for omitting work	
subtract up to 2 points for incorrect answer on each equation in the problem	
Ray Diagrams – 8 points each(#17 & 18)	16 points
Diagram and scale correct – 3 points	
Image location correct – 2 points	
Image size correct – 2 points	
Image type correct – 1 point	

APPENDIX E

NAME________________________ DATE____________________ HR__________

PHYSICS HP- WAVES AND SOUND
PRE/POST TEST

Short Answer Questions. Read and answer the following questions. Explain your answers

1. Draw a wave and label the features (use a sine curve for the wave).

2. Explain why we hear sounds over a longer distance at night.

3. What allows a clarinet or trumpet to play different notes?

4. Explain the relationship between the period and frequency of a wave.

5. In the movies, you can hear and see a rocket explode in outer space. Explain why this is scientifically incorrect.

6. In old movies, cowboys hear a train coming by putting their ears on the train track. What is the reason for this?

7. What happens to light and sound waves when they travel from air into water?

RUBRIC AND ANSWERS
PHYSICS HP- WAVES AND SOUND
PRE/POST TEST

Short Answer Questions. Read and answer the following questions. Explain your answers

1. Draw a wave and label the features (use a sine curve for the wave).

   1 point for drawing a sine curve. 1 point each for labeling the crest, trough, amplitude and wavelength.

2. Explain why we hear sounds over a longer distance at night.

   1 Point. Accept either: Air is more dense, sound there are more particles for the sound to travel through or cooler temperatures refract sound towards the ground.

3. What allows a clarinet or trumpet to play different notes?

   1 point. Length of air column is changed, which changes the wavelength of the column. Shorter wavelength means higher frequency, which gives higher pitch.

4. Explain the relationship between the period and frequency of a wave.

   1 Point. They are inversely proportional.

5. In the movies, you can hear and see a rocket explode in outer space. Explain why this is scientifically incorrect.

   2 points. Sound cannot travel in a vacuum and even if it could, sound is so much slower, the explosion would be seen and heard at different times. (1 point for each reason)

6. In old movies, cowboys hear a train coming by putting their ears on the train track. What is the reason for this?

   1 point. Sound travels faster in a solid, so the sound is heard through the track before in the air

7. What happens to light and sound waves when they travel from air into water?

   2 points. The waves hit a boundary, change speed and bend or refract.

APPENDIX F

Physics Survey
Fall Semester 2001

Part 1: Please read each statement carefully, then circle the number that reflects your opinion. Use the following scale:

1	Strongly Agree
2	Somewhat Agree
3	Feel Neutral
4	Somewhat Disagree
5	Strongly Disagree

This unit help me understand how instruments with strings make music.	1 2 3 4 5
Constructing my own instrument was useful in helping to understand how sound travels.	1 2 3 4 5
I enjoyed the Reflection and Refraction Lab-a-thon.	1 2 3 4 5
The Lab-a-thon was useful in explaining reflection and refraction.	1 2 3 4 5
The homework made the material easier to understand.	1 2 3 4 5
I preferred the math-style homework over the Think and Explain questions.	1 2 3 4 5
What I learned exceeded my expectations at the beginning of this unit.	1 2 3 4 5
The use of the computer made the material easier to understand.	1 2 3 4 5

(Over, please)

Part 2: Please read each question carefully, and write a short answer.

Which part of this unit did you like best and why?

Which part of this unit did you like least and why?

What do you think would have helped you understand this unit better?

APPENDIX G

LON-CAPA
SAMPLE CONTENT AND PROBLEM PAGES

Introduction to Waves

Suppose you were to tie a rock on the end of a string. You could hold the string and allow the stone to swing back and forth. If the angle of release were small, the stone would swing back and forth in what is called "simple harmonic motion". Drawing a picture of that motion would give you a picture of a wave (the shape would be a sine curve).

We can describe simple harmonic motion mathematically! The following equation is used to determine the period of a pendulum:

$$T = 2\pi(L/g)^{1/2}$$

A wave is no more than a wiggle in space and time. In the above pendulum, the wave is produced by the back and forth motion of the rock. If the rock were attached to a spring instead, the bobbing motion of the rock would produce the wave motion.

There are many other ways of producing a wave. A stone dropped in a pond produces a wave, sound produces waves, light travels in a wave and there are lots of others. This chapter is a general introduction to waves. Enjoy!

Wave Speed

The speed of a wave depends on the medium the through which the wave travels. Generally speaking waves travel fastest through solids, slower through liquids and slowest through gases. While the speed of sound waves in air varies greatly, the speed of electromagnetic waves is considered constant. The speed of electromagnetic waves is given the symbol c, and the value is 3.0×10^8 m/s. The equation used to determine wave speed is: $V=\lambda f$. (speed = wavelength times frequency)

Example

The string of a violin vibrates with a frequency of 264 Hz, producing the middle C note. If the sound waves produced by this string have a wavelength in air of 1.30 m, what is the speed of sound in air?

$$v=\lambda f$$
$$v=(1.30\text{m})(264\text{ Hz})$$
$$v=343\text{ m/s}$$

What is the period of the violin string?

$$T=1/f$$
$$T=1/264\text{Hz}$$
$$T=3.79 \times 10^{-3}\text{ s}$$

Sample Page – Solved Problems

Identify the following as properties of a sound wave, an electromagnetic wave, or both.
sound wave: Must travel through a medium.
both: Has amplitude, crests, and troughs
electromagnetic wave: Is a transverse wave
both: Frequency can be found by dividing the speed by the wavelength.

You are correct. Your receipt is 490-1244

What is the speed of a wave with a wavelength of 1.80 m and a frequency of 186.1 Hz?
The computer got 335 m/s.

Tries 0/10

A hiker shouts toward vertical cliff 696 m away. The echo is heard 4.12 s later. Calculate the speed of sound in air.
The computer got 337.864077669903 m/s.

Tries 0/10

The wavelength of the sound wave is 0.8 m. What is the frequency of the wave?
The computer got 422.330097087379 Hz.

Tries 0/10

A radio station broadcasts at a frequency of 91.7 MHz. What is the wavelength of the radio waves?
The computer got 3.27153762268266 m.

Tries 0/10

A pendulum has a length of 1.2 m. What is the period of the pendulum? (You may use 9.81 m/s^2 for g.)
The computer got 2.19753594576947 s.

Tries 0/10

The prince has come to save Rapunzel, who is trapped at the top of a tower. She lowers her braided hair for the prince to climb. He holds on to her hair, and begins to sway back and forth, like a pendulum. How high is the tower if the prince has a period of 5.75 seconds? (use 9.81 m/sec^2 for g).
The computer got 8.21570733281368 m.

Tries 0/10

An electromagnetic wave has a frequency of $6.3x10^{14}$ Hz. What is the period of the wave?
The computer got 1.58730158730159e-15 s.

Tries 0/10

On planet E a pendulum with a length of 1.25 m has a period of 4.6 s. Calculate the gravity on this planet.
The computer got 2.33213714581507 m/s^2.

Tries 0/10

Bats emit ultrasonic sound to help them locate obstacles. The sound waves have a frequency of 2.00e+04 Hz. If the waves travel at 317 m/s what is the wavelength of the waves?
The computer got 0.01585 m.

Tries 0/10

Sample Page – Unsolved Problems

Light travels from crown glass into air. The angle of refraction in the air is 53°. What is the angle of incidence in the glass?

Submit Answer

Tries 0/10

What is the index of refraction of a medium if the angle of incidence in air is 50° and the angle of refraction is 38°?

Submit Answer

Tries 0/10

One ray of light strikes a material that has an index of refraction of 1.65. Another ray of light strikes a material that has an index of refraction of 2.25. In each case the angle of incidence is 35°. What is the difference between the angles of refraction?

Submit Answer

Tries 0/10

Marlo shines a laser into a pool. The laser light strikes the water at an angle of 50.6°. What is the angle of refraction?

Submit Answer

Tries 0/10

From inside an aquarium a ray of light is directed toward the glass so the angle of incidence is 33 °. Determine the angle of refraction when the ray emerges into the air.

Submit Answer

Tries 0/10

Submit All

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