COMMUNICATIONS SYSTEMS UNIT

GRADE 12 SCIENCE

University and College Preparation (SNC4M)

Science Teachers' Association of Ontario

Promoting Excellence in Science Education Through Leadership & Service

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Foreword

This document is designed to assist teachers, especially teachers without a strong background in Physics, to plan and structure the Communications unit in SNC4M.
It includes eight activities, and the outline for a research project.
There are two more activities in the appendix for teachers and students who want to explore the topic in more detail.
There is also an appendix listing a large number of web sites.
Please remember that the Internet is a changing environment, and web sites do change. These sites were all active at the time of writing.
The addition of a number of multiple choice questions is not to indicate that only that type of question is to be used, but to enable teachers to have access to a bank of multiple choice questions.

Acknowledgements:

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Safety Precautions

In experiments 2 and 3 warn the students not to allow the slinky to slip out of their hand, it could flex and hurt them.

Whenever you are using a retort stand to support a load, make sure that the retort stand is secured to the surface. The best way to achieve this is by means of a C-clamp.

In any experiment where you are using an electric appliance be aware that

- It must have a CSA or UL seal of approval.
- Ensure it has a grounding pin (a third pin).
- Plug it in a properly grounded outlet.
- Do not use one with frayed wires.
- Pull the plug, not the wire, when unplugging it.
- Be sure the wires are out of the way of other equipment.
- Do not exceed 6 V

If you are using an umbrella in the Supplemental Experiment on Radio Waves, be sure its long handle does not get in the way of the other equipment.

Lab 1 The Simple Pendulum

Purpose

The purpose of this activity is to determine the factors that affect the period of vibration of a simple pendulum.

Materials

Various lengths of string, various masses, stopwatch.

Procedure

Securely attach a string to a rigid structure. Make sure that the pendulum can swing freely.

1. Draw back the pendulum, and measure the distance that the pendulum bob has been moved from its starting position. This is the *amplitude*. With a stopwatch measure the length of time it takes for the pendulum bob to make 10 complete back and forth motions (*cycles*). Divide this time by 10 to obtain the *period of vibration*.
2. Repeat the experiment, using several different amplitudes.
3. Repeat the experiment, using several different pendulum bobs.
4. Repeat the experiment, but change the length of the string.

Record your measurements in the following table.

Length (cm)	Amplitude (cm)	Mass of Bob (g)	Total time (s)	Period T (s)	Frequency f (Hz)

Lab 1 The Simple Pendulum
Teachers Notes

Purpose

The purpose of this lab is twofold. One purpose is to introduce some of the basic terms used in the study of waves. These are
Cycle, Amplitude, Period of vibration, and *Frequency*

A *cycle* is one complete back and forth motion of the wave.
The *amplitude* of a wave is the *maximum* displacement, measured perpendicular to the rest position of a wave.
The *Period of vibration* of a wave is the time for *one* cycle.
The *frequency* of a wave is the number of cycles every second. This is measured in *Hertz (Hz).*

The second purpose of this lab is to show that the only factor which determines the period of a pendulum is the length of the string.

> This is historically important, because, according to legend, Galileo made this observation while he was watching the hanging candles swing while he was in church. This led to the development of the "Grandfather Clock", which was the first accurate method for measuring time.
> **The subject of "methods of measuring time" could be an excellent research topic.**

Introduction

It is important that the string is fixed to a rigid object. Retort stands tend to wobble, especially with bobs which have a greater mass. Suspending the pendulum from the ceiling is great, if that option is available. If you have the typical suspended ceiling stick with retort stands, but clamp them to the table.
If you use masses of 50 g, 100 g, and 200 g, the height of the masses is important, because the length of the pendulum is measured from the point where the string is tied to the centre of the mass. So with a longer mass the string should be shortened, so that the length remains the same.
Three different values for each variable (amplitude, mass, and length of string), are sufficient to get good observations.
Another option is to draw graphs of "T vs. each variable".

Observations

The key observation is that the amplitude, and pendulum bob mass have no effect on the Period of a wave. The only factor, which determines the Period of a wave, is the length of the string.
Another observation should be the relationship between period and frequency, namely $f = 1/T$

This means that a Hertz, is actually 1/seconds, or, as some text books write it, s^{-1}

Summing Up

This is a good activity to start with, because it allows you to reinforce some of the basic terms dealing with waves, and it also allows you to talk about variables, and the importance of changing only one variable at a time

The difference between a *wave* and a *pulse* should be briefly discussed. A *pulse* is a single disturbance moving along a medium, while a *wave* is a continuous series of *pulses* moving along a medium. For the sake of simplicity we tend to use the terms interchangeably because it is difficult and confusing to draw actual wave diagrams, when it is much simpler to draw only one pulse, which represents what is happening to the series of pulses, namely the wave.

Lab 2 SPEED OF A WAVE

Purpose

The purpose of this activity is to measure the velocity of a transverse wave in a spring, and to determine the factors that affect the velocity.

Materials

Slinky, (or heavy metal spring), stopwatch, and a metre stick

Procedure

Comparing the velocity of waves.

Waves can be generated in a Slinky stretched out on a floor between two students. (Be careful not to stretch the Slinky too much, or it will be permanently deformed.) Have a third student give one end a single quick jerk sideways and back. This is called a transverse pulse.

1 With a stopwatch measure the length of time it takes for the pulse to travel the length of the Slinky and back. Take several readings.
2 Measure the length of the Slinky, double the length, divide by the time and calculate the speed of the wave.
3 Repeat the experiment, using several different amplitudes.
5 Repeat the experiment, using several different frequencies.
6 Change the tension in the Slinky, by stretching it more and measure the speed of the wave now.

Record your measurements in the following table. Remember that velocity is total distance/ average time.

Wave description	Times (s)	Average Time (s)	2x length Slinky (m)	Velocity (m/s)
Medium amplitude, medium frequency				
Small amplitude, medium frequency				
Large amplitude, medium frequency				
Medium amplitude, Low frequency				
Medium amplitude, high frequency				
Higher tension				

Lab 2 SPEED OF A WAVE
Teachers Notes

Purpose

The purpose of this activity is to measure the speed of a transverse wave in a spring, and to determine the factors that affect this speed.

Introduction

Most Physics departments have “Super” Slinkies, which can be stretched to a length of 5- 6 m without affecting the Slinky.
You can change the amplitude of the pulse by changing how far you pull the Slinky sideways at the start. You can compare the speeds for small, medium, and large amplitudes.
To change the frequency of the pulse, remind the students that frequency and period are inversely related. Therefore if you give the Slinky a quick jerk, the frequency of the wave will be large. To get a low frequency pull the Slinky more slowly sideways.
Frequency actually refers to a periodic wave that is a continuous series of identical pulses. In this experiment it is easier to make observations if we use only one pulse, so when we talk about frequency we are assuming what would happen if we had a continuous series of pulses.
The time measurement is the largest source of error, so use as many stopwatches as you have, and find the average time. The more students you have measuring the time, the better your results.

Observations

The key observation is that the frequency and amplitude have no effect on the speed of a wave. The only factor which determines the speed of a wave is the medium through which it travels.

Summing Up

Relate the results of this activity to music. If the speed of sound depended on the amplitude then a sound of different loudness produced by a band would travel at different speeds, and reach the back of an auditorium at different times. Likewise with different frequencies, sounds of different pitch would travel at different speeds.
An important point to make is that the “same” medium can act as “different” medium, for example sound travels faster in hot air than cold air.
A bullwhip can demonstrate the increase is speed as the wave travels along the whip. The whip decreases in diameter, therefore the speed of the wave increases, until the tip of the whip moves at the speed of sound, and the sound barrier is broken, and a loud crack is heard. (See http://www.sigmaxi.org/amsci/Issues/Sciobs02/02-09sciobsmath.html)

Lab 3 Detailed Analysis of Pulse Transmission/Reflection

Purpose
How are pulses both transmitted (passed through) and reflected (bounced back) when traveling from one medium to another?

Materials
One Slinky (8 cm. diameter, 10 cm. length, 16 turns per centimetre), one heavy coil spring (2 cm. diameter, 180 cm. length, 8 turns per centimetre), one length of string, metre stick.

Procedure and Observations

1. Transmission of a transverse pulse
Place a large, light spring (a Slinky) on a smooth floor and stretch it to a length of approximately 6 m. Determine the best stretch distance for your coil by trial and error, being careful not to exceed the stretch limit of the spring being used. Station group partners at each end of the Slinky to hold it securely in position while stretched.

CAUTION: **Avoid releasing an end of the stretched spring; untangling a Slinky can be very difficult.**

With the ends of the stretched Slinky held rigidly in place, form a pulse by grasping a loop near one end of the spring and displacing it to one side by a *quick* back-and-forth motion of the hand. Practice this motion until a pulse can be formed that travels down only one side of the spring. Why is the pulse called a *transverse pulse?*

Observations:

a) The pulse travels down the length of the Slinky but each individual coil actually moves____________________________. (along the length, or perpendicular to it.)

b) The coil spring is the medium through which the pulse travels. Send a short pulse down the spring. How does its size or shape change? _________________ Can you suggest a reason? _________________________Upon what does the initial amplitude of the pulse depend? ________________________________Does the speed of the pulse appear to change with its size? ___________________

2. Reflection of Pulse from Fixed-End (phase and amplitude)
With the far end of the Slinky held firmly in place (fixed-end termination), send a single pulse down one side of the spring. Observe the reflected pulse.
(a) Compare the amplitude of the reflected pulse with that of the transmitted pulse just before reflection.
(b) What is the phase of the reflected pulse relative to the transmitted pulse?

Observations:

(a)____

(b) ____

3. Reflection of Pulse from Free-End

Attach a light string about 2 m long to the far end of the Slinky and maintain the tension on the spring by holding the end of the string. This approximates a *free-end* termination for the Slinky.
(a) Send a pulse down one side of the spring as before and observe the pulse reflected from the "free" end.
(b) Compare reflection from the "free" end of the spring with reflection from the fixed end.

Observations:

(a) ____

(b) ____

4. Energy Transfer through an Interface (heavy spring—Slinky)
Investigate the transfer of a pulse from one medium to another by attaching the heavy metal spring to the end of the Slinky. Would you expect the pulse speed to remain the same in both sections of the stretched combination? ______________________
To the extent that the second spring produces an impedance mismatch at its junction with the Slinky, the pulse energy arriving at the junction will be partly reflected and partly transmitted.
Send a pulse down one side of the heavy spring toward -the junction and observe:
(a) the phase of the pulse **reflected** at the junction as compared to the original phase
(b) Similarly determine the relative phase of the pulse transferred across the junction to the Slinky.

Observations:

(a) ____

(b) ____

5. Energy Transfer through an Interface (Slinky—heavy spring)
Switch ends and *repeat* these phase observations for a pulse sent down the Slinky and toward the junction with the heavy spring.
a) Send a pulse down one side of the Slinky toward the junction and observe the relative phase of the pulse reflected at the junction
b) Similarly, determine the phase of the pulse *transferred* across the junction to the heavy string, relative to the incident pulse.

Observations:

a) ____

b) ____

Notice how the speed changes in the different coils. Which type of coil allows the pulse the fastest?
If the difference in pulse speeds in the two springs was even greater, a different proportion of the pulse energy would be reflected or transmitted at the junction between the media.
In electronics this is called an impedance mismatch and needs to be eliminated or reduced to a minimum.

<u>Analysis and Summary</u>

1. The pulse speed remains constant in a medium even though its ______ (also called ___________) decreases due to energy losses caused by ___________. Even though the pulse energy travels longitudinally (down along the length of the Slinky) the individual coils move at ____^{0} to the axis of the Slinky which is why this is a _______________ pulse or wave. The frequency or amplitude of the source, your hand, determines the ________________ or ________________ of the resultant pulse.

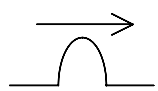
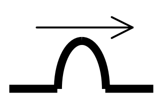
2. When the Slinky's far end was held in place, fixed-end termination, a transmitted crest would be reflected as a __________ and a transmitted trough would be reflected as a ________. This is called *out of phase* reflection.

3. When the Slinky's far end was attached to a string of negligible mass, a transmitted crest would be reflected as a ___________, and a transmitted trough would be reflected as a __________. This is called *in phase* reflection. Since the mass of the string is so small compared to the mass of the Slinky this approximates a *free-end* termination of the Slinky.

4. The pulse that traveled from the heavy spring to the Slinky reflected in a manner similar to_________-end termination. Crests reflected back as _________ and troughs reflected back as __________. In addition, there was a pulse transferred through the interface which was transmitted _________ (in) or (out of?) phase so that a crest sent down the heavy spring) continued down the Slinky as a _____________. Similarly, a transmitted trough would continue through the heavy spring-Slinky interface and keep going as a _____________. This phenomenon is known as partial reflection/partial transmission since some of the pulse energy is __________ and some of the pulse energy is ______________.

5. The pulse that traveled from the Slinky to the heavy spring reflected in a manner similar to ________-end termination. Crests reflected back as ___________ and troughs reflected back as __________. Once again, there as also a transmitted pulse which was transmitted ________ *phase,* so that a crest sent down to the heavy spring from the Slinky would be transmitted as a ___________ and a trough would be transmitted as a ________. Again partial reflection/partial transmission occurred since a transmitted pulse would reflect back and also _______________ through the interface.

<u>Summary</u>

Light to Heavy Medium	**Original Pulse**	**Reflected**	**Transmitted**
Draw in the 2 remaining pulses. (Show correct phase and amplitudes)			
Heavy to Light Medium	**Original Pulse**	**Reflected**	**Transmitted**
Draw in the 2 remaining pulses. (Show correct phase and amplitudes)			

Lab 3 Partial Reflection, Partial Transmission Teachers Notes

Purpose

This is a detailed activity, which requires students to experientially determine various types of reflection and transmission using a Slinky and a heavier spring coil.

Introduction
This activity requires some teacher coaching to:
Help students to make a good compact U shaped pulse.
Direct students to use the terms *crest* to describe a pulse that is oriented on one side of the Slinky to easily describe/differentiate the opposite side pulses as *troughs*.
Focus on either the transmission or reflection. It is hard to carefully observe both at once.

Observational Results

1. Transmission of a transverse pulse
The pulse travels down the length of the Slinky but each individual coil actually moves transversely or at right angles to the motion.
b) The coil spring is the medium through which the pulse travels. Send a short pulse down the spring. How does the size or shape change? No shape change, some decrease in size
Can you suggest a reason? Energy losses to friction Upon what does the initial amplitude of the pulse depend? The size of the motion of the hand/source vibrating the Slinky. Does the speed of the pulse appear to change with size? No
2. Reflection of Pulse from Fixed-End (phase and amplitude)
With the far end of the Slinky held firmly in place (fixed-end termination), send a single pulse down one side of the spring. Observe the reflected pulse.
(a) Compare its amplitude with that of the transmitted pulse just before reflection.
(b) What is its phase relative to the transmitted pulse?

Observations:

a) The amplitude is unchanged (maybe slightly smaller)
b) The phase is inverted (crest bounces back as a trough)

3. Reflection of Pulse from Free-End
Attach a light string about 2 m long to the far end of the Slinky and maintain the tension on the spring by holding the end of the string. This approximates a *free-end* termination for the Slinky.
a) Send a pulse down one side of the spring as before and observe the pulse reflected from the "free" end.
b) Compare reflection from the "free" end of the spring with reflection from the fixed end.

Observations:

(a) The phase is the same (crest bounces back as a crest)
(b) This result is opposite to the fixed end

4. Energy Transfer through an Interface (heavy spring—Slinky)
Investigate the transfer of a pulse from one medium to another by attaching the heavy metal spring to the end of the Slinky. Would you expect the pulse speed to remain the same in both sections of the stretched combination? No, the type of medium and its properties determine speed not the size of pulse
To the extent that the second spring produces an impedance mismatch at its junction with the Slinky, the pulse energy arriving at the junction will be partly reflected and partly transmitted.
Send a pulse down one side of the heavy spring toward -the junction and observe:
a) the relative phase of the pulse **reflected** at the junction.
b) Similarly determine the relative phase of the pulse transferred across the junction to the Slinky.

Observations:

a) The reflected pulse phase is the same (crest bounces back as a crest from the junction of the two different Slinkies)
NOTE: This reflection is from the junction of the two springs, not from the person's hand at the far end.
b) The transmitted pulse phase is the same (crest continues as a crest)

5. Energy Transfer through an Interface (Slinky—heavy spring)
Switch ends and *repeat* these phase observations for a pulse sent down the Slinky and toward the junction with the heavy spring.
(a) Send a pulse down one side of the Slinky toward the junction and observe the relative phase of the pulse reflected at the junction. (b) Similarly, determine the relative phase of the pulse *transferred* across the junction to the heavy string
Observations:
a) The reflected pulse phase is opposite (crest bounces back as a trough from the junction of the two different Slinkies)
b) The transmitted pulse phase is the same (crest continues as a crest)

If the difference in pulse speeds in the two springs was even greater, a different proportion of the pulse energy would be reflected or transmitted at the junction between the media.
In electronics this is called an impedance mismatch and needs to be eliminated or reduced to a minimum.

Analysis and Summary (Answers)

1. The pulse speed remains constant in a medium even though its size or amplitude decreases due to energy losses caused by friction. Even though the pulse energy travels longitudinally (down along the length of the Slinky) the individual coils move at 90^0 to the axis of the Slinky which is why this is a transverse pulse or wave. The frequency or amplitude of the source (your hand) determines the frequency or amplitude of the resultant pulse.

2. When the Slinky's far end was held in place (fixed-end termination) a transmitted crest would be reflected as a trough and a transmitted trough would be reflected as a crest. This is called *out of phase* reflection.

3. When the Slinky's far end was attached to a string (of negligible mass) a transmitted crest would be reflected as a crest and a transmitted trough would be reflected as a trough. This is called *in phase* reflection. Since the mass of the string is so small compared to the mass of the Slinky this approximates a *free-end* termination of the Slinky.

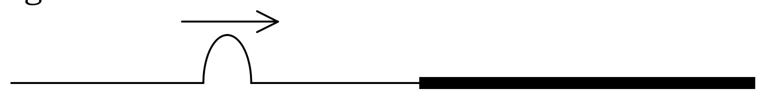
4. The pulse that traveled from the heavy spring to the Slinky reflected in a manner similar to free-end termination. Crests reflected back as crests and troughs reflected back as troughs. In addition, there was a pulse transferred through the interface that was transmitted in phase so that a crest sent down the heavy spring (traveling through the interface) continued down the Slinky as a crest. Similarly, a transmitted trough would continue through the heavy spring-Slinky interface and keep going as a trough. This phenomenon is known as partial reflection/partial transmission since some of the pulse energy is reflected and some of the pulse energy is transmitted

5. The pulse that traveled from the Slinky to the heavy spring reflected in a manner similar to *fixed*-end termination. Crests reflected back as troughs and troughs reflected back as crests. Once again, there as also a transmitted pulse which was transmitted in *phase,* so that a crest sent down to the heavy spring from the Slinky would be transmitted as a crest and a trough would be transmitted as a trough. Again partial reflection/partial transmission occurred since a transmitted pulse would reflect back and also transmit through the interface.

The best way to show a pulse in this experiment is to use a light and a heavy line to show the different materials.

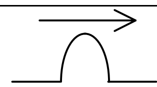
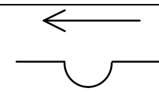
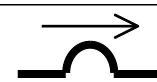
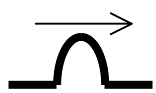
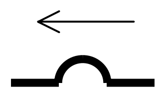
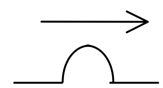
It is important to point out that the lighter line represents the less dense material, the physically larger Slinky. The heavy line represents the denser material, the heavy coil, with the smaller diameter.

In the diagram below the Slinky is on the left, the heavier coil on the right



When a pulse moves from a less dense to a more dense material the reflection has a smaller amplitude, and is inverted. The transmitted part of the wave, in the denser material, is not inverted, and also has a smaller amplitude.

When a pulse moves from a denser to a less dense material the reflection has a smaller amplitude, and is not inverted. The transmitted part of the wave, in the less dense material, is not inverted, and also has a smaller amplitude.

Light to Heavy Medium	**Original Pulse**	**Reflected**	**Transmitted**
Draw in the 2 remaining pulses. (Show correct phase and amplitudes)			
Heavy to Light Medium	**Original Pulse**	**Reflected**	**Transmitted**
Draw in the 2 remaining pulses. (Show correct phase and amplitudes)			

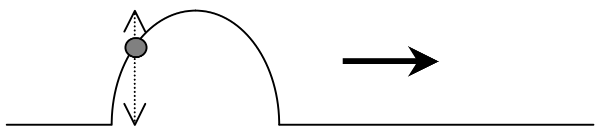
If you want to use a word list for the "Fill In The Blanks" exercise here is one. Please point out to the students that some terms may be used more than once.

reflected	free-end
crest(s)	friction
trough(s)	size
fixed-end	transmit
90°	amplitude

transmitted	frequency
transverse	

Exercise 1 Superposition of Waves

When a pulse (a single wave) moves along a medium we see the effect that the pulse has on the medium



For a transverse wave, each particle in the string can only move perpendicular to the direction in which the wave moves. The range of motion of a particle is shown by the dotted line in the above diagram.

An interesting question is "In what direction is the particle moving at the instant shown above?" The correct answer is "down". The way to understand that is to imagine the pulse an instant later. The wave will have moved a bit to the right. Therefore, since the particle is still on the wave, and can only move up or down, it must be down.

If two pulses move along a string there is no problem if they do not overlap. When they overlap it gets more interesting, because each particle of the medium can only be in one place at one time. The shape of the string now is the result of the combined effect of the two pulses.

The easiest way to understand this is to think of each of the two pulses exerting a force on the particle. So if the first wave would have moved the particle up 2 cm, and the second wave would have moved up the particle 3 cm, then this particle will be 5 cm above its rest position. This is an example of *constructive* interference, because both forces act in the same direction.

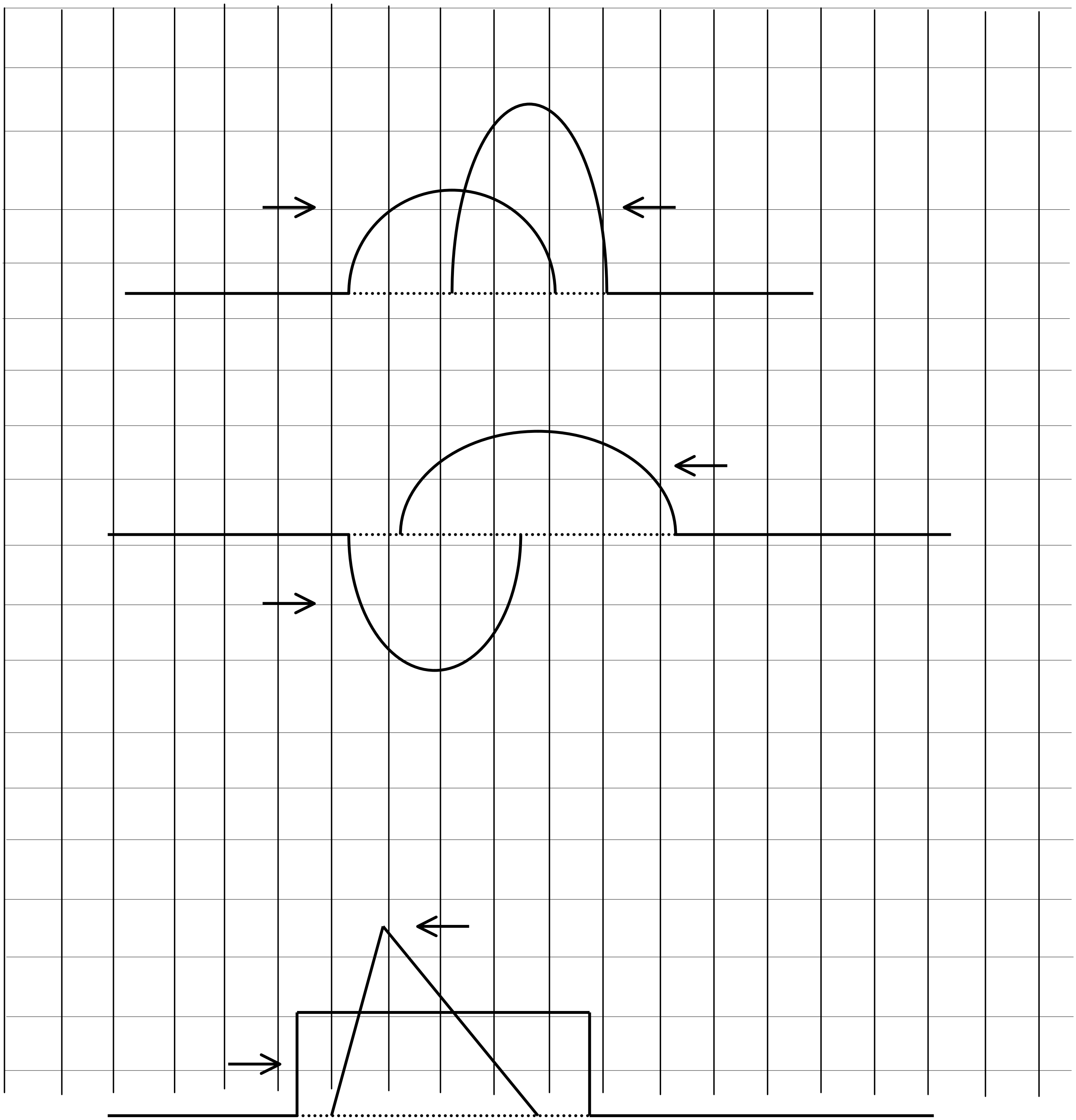
If one wave was above the rest position, while the other was below, you subtract the displacements. For example if the wave on the left would have moved the particle up 2 cm, while the second wave would have moved the particle 5 cm down, then the particle will actually be 3 cm below the rest position. This is an example of *destructive* interference, because the forces act in opposite directions.

On the following page are three examples students can use to practice superposition.

The student should choose 3 or 4 points in the region where the pulses overlap. From each of these points draw a vertical line, up and down. This is the line along which the particle can move. First measure the length of the line from the rest position to the first wave (for example 3.5 cm up), then do the same thing for the second pulse (for example 5.2 cm up), and then determine the sum (8.7 cm up). Measure that distance up from the rest position, and this will be the displacement of that particle at that instant of time.

Repeat this for the other points, and then connect the points to show the shape of the wave at that instant.

It is important to note that this is a momentary shape. After an instant of time later both pulses will have moved, and the resultant shape will be different.



Lab 4 The Speed of Sound

Purpose
The purpose of this activity is to measure the speed of sound.

Materials
Two small wooden boards, stopwatches, measuring tape.

Procedure
Find a quiet location outside where there is a large flat wall, like the side of a building. The quieter the better.
Have a student stand 50 to 60 metres from the wall. Facing the wall, have the student clap the boards together and listen for the echo.
Have the student clap the boards so that the clap is produced when the echo is heard. Practice this.
Have several students use their stopwatches to measure how long it takes for 10 claps.

Observations
Measure the distance from the student to the wall. Calculate the time it takes the sound to go to the wall and back, by taking the total time for 10 claps and dividing by 10.

Calculations
To find the speed of sound double the distance to the wall, and divide by the time for one back and forth trip.

Lab 4 The Speed of Sound
Teachers Notes

Purpose
The purpose of this activity is to measure the speed of sound.

Materials
Two small wooden boards, stopwatches, measuring tape.

Procedure
A good set of boards to use would be two 2x4's, about 15 cm long.

Observations
If there is no large flat wall available, or the weather is poor, this experiment can be done in a long hallway

In this experiment it is important that you do some homework beforehand. You should have an idea of what the expected results are. Assume the speed of sound is about 340 m/s, and that a reasonable clap rate is about 3 per second. So sound will travel about 110 m in 1/3 of a second. This means you should be about 55 m from the wall.

When you do the experiment have the student with the boards stand about 55 m from the wall. This should result in a clap rate of about 30 for 10 seconds. If your results are too far off, ask for a repetition.

This is a good experiment to illustrate experimental errors, because the measurements are very accurate; the problem is with human error.

Make sure that students don't just put down "human error", ask for a more specific example, such as the reaction time to start and stop the stopwatches.

Demonstration Resonance in a String

Purpose

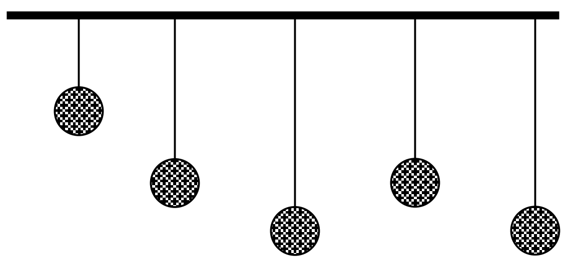
The purpose of this demonstration is the illustrate resonance and the conditions necessary for resonance.

Materials

Various lengths of string, four pendulum bobs

Procedure

Securely attach a piece of surgical tubing, about 1 m long between two rigid points. Most text books use two retort stands, but if you can find more rigid points such as desks the results will be better.
To the rigid tube hang four strings. Make sure that two of the strings are exactly the same length, while one of the remaining strings is shorter, the other longer.



Pull back any one of the bobs and release it. You should observe that when one of the pair of strings of equal length starts to oscillate its amplitude decreases. The second string, of the same length will slowly start to oscillate. The first one almost stops, while the second one will oscillate strongly. After a while the process will reverse itself.

Explanation

All objects have a ”fundamental frequency”. When vibrations of that frequency strike that object it will start to vibrate in sympathy. That phenomenon is resonance.
A simple example is a child on a swing. The swing has a “fundamental frequency” which is determined by its length. To increase the amplitude of the swinging, you must push the swing with that frequency. So you push when the child is always in the same position, and push in the direction of the child’s motion.

Another example of resonance is a rattle in a car. A loose part in the car vibrates at a certain natural frequency. A car engine vibrates, and the frequency of the vibration depends on the speed of the car. So when the frequency of the engine is the same as the natural frequency of the loose part that part starts to vibrate, causing a rattle. If the engine vibrates faster or slower the conditions for resonance are not present.
Resonance can also be demonstrated nicely if you have two tuning forks (they must be mounted on resonance boxes). The tuning forks must have identical frequencies. Face the open ends and strike one of the forks. The put your hand over this tuning fork, and the sound will still be there, because the second fork is now vibrating. Guitar strings also resonate in this manner.
If you use tuning forks of different frequencies there will be no resonance

This property of resonance is used in the transmission of radio signals. Every radio station sends out a signal of a certain frequency. For example station 99.3 sends out FM signals that have a frequency of 99.3 MHz. When your radio is tuned to 99.3 the signals from that station cause the electrons in the antenna to resonate, and your radio will then further amplify them. AM and TV stations work on the same principle.

Lab 5 The Law of Reflection

Purpose

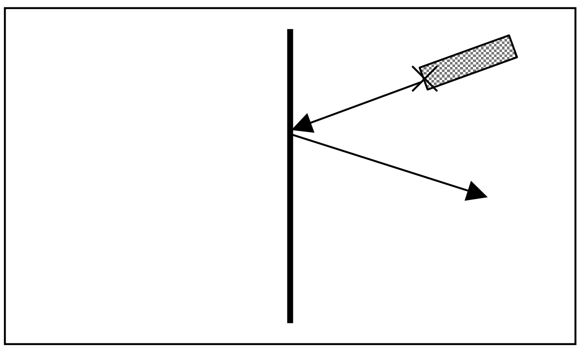
The purpose of this activity is to find the first law of reflection.

Materials

Piece of paper, plane mirror, ray box, protractor.

Procedure

Set up the piece of paper sideways, and draw a vertical line across the paper.
Mark a point X to one side of the paper in front of the mirror.



Set up a plane mirror along the vertical line drawn.
Aim the raybox so that a ray of light starts at the point X, and hits the mirror. With a pencil mark a dot on the *incident ray*, the point where the ray hits the mirror, and a point on the *reflected ray*. Put a number 1 beside each of these points.
Repeat this with 3 more light rays, marking 3 more points, 2, 3, and 4.but make sure that the opening of the ray box remains on the same starting point (X)
Construct 4 *normals*, one from each of the points where the rays hit the mirror. (A normal is a line perpendicular to the surface at the point where the incident ray strikes the mirror.)
Measure the *angles of incidence* and *reflection*, and record the values in the following table. (The angle of incidence is the angle between the incident ray and the normal. The angle of reflection is the angle between the reflected ray and the normal.)

Angle of incidence	Angle of reflection

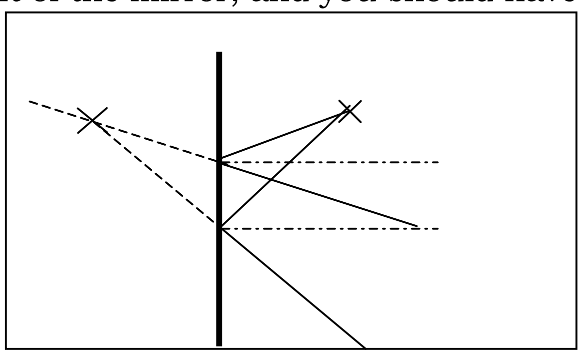
<u>Lab 5 The Law of Reflection</u>

Teachers Notes

Introduction

Before the student starts this experiment make sure that the ray is as narrow as possible. This can be achieved by moving the lens back and forth, until the beam is as narrow as possible. Also make sure the mirror is not leaning, and that the ray box sits flat on the paper.

The diagram should look something as follows. (Without the dotted lines on the left of the mirror, and you should have 4 sets of lines)



Observations

When you measure the angles you should observe that the *angle of incidence* is equal to the *angle of reflection.*

After the students have completed the experiment ask them to extend the lines representing the *reflected rays* behind the mirror (Dotted lines in the above diagram). If the rays were drawn accurately they should meet at one point. This point should be the same distance behind the mirror as the original point X was in front of the mirror, and the line joining the points should be perpendicular to the mirror.

By the way this is an easy way to check the accuracy of the experiment, without measuring the angles.

This observation is a nice lead-in to the discussion of *images.* The *object* is where all the incident rays come from, and the *image* is where all the reflected rays meet, or seem to meet.

An image can be described by three characteristics. One is size (smaller, larger or the same size), another is orientation (erect or inverted) and the third is type (real or virtual). If the reflected rays actually meet then the image is *real.* If the reflected rays have to be extended behind the mirror, the image is a *virtual* image.

Lab 6 Refraction

Purpose

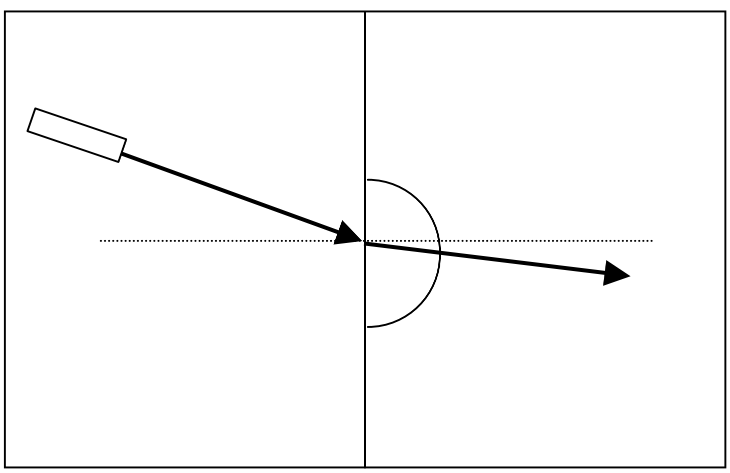
The purpose of this activity is to observe refraction and to derive the law of refraction

Materials

Ray box, semi-circular water tank, semi-circular solid plastic block, protractor

Procedure and Observations

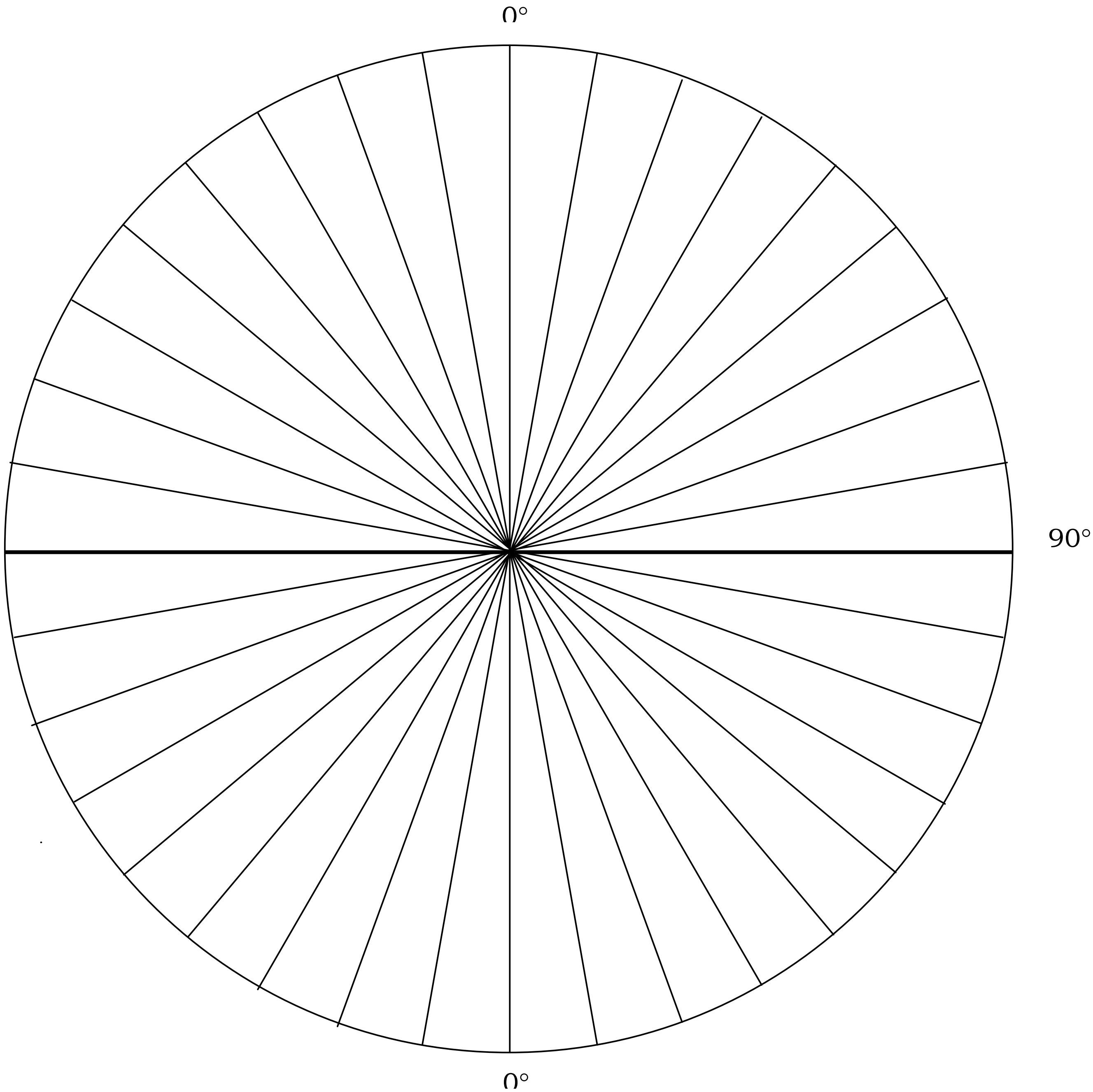
Draw a line across a piece of paper, as shown in the diagram below.
Place the flat side of the water tank along this line. Mark the center point.
Draw a perpendicular line to the water tank at the center point.
Position the ray box so that the ray strikes the exact center point. Trace this line.
Locate the point where the ray leaves the water tank, and mark it as exit point 1
Move the ray box so that the ray strikes the center point, but with a different angle of incidence.
Repeat this until you have 3 or 4 pairs of incident and refracted rays.
Repeat the experiment, using the plastic block instead of the water tank.
Record the angles in the table below.
Remember all angles are measured to the normal



Air to water		Air to plastic	
Angle of incidence	Angle of refraction	Angle of incidence	Angle of refraction

Lab 6 Refraction
Teachers Notes

Please read the Teacher's Notes after the next experiment.
It is a good idea to start with the plastic block, because the light rays are more visible.
Another great idea is to use a polar coordinate graph paper. Line up the 0° line with the normal, and students will find it easier to measure the angles.
Place the straight side of the water tank or the plastic block along the 90° line, and then the normal will be along the 0° line, and all the angles will be measured from the 0° lines.



Lab 7 Critical Angle and Total Internal Reflection

Purpose

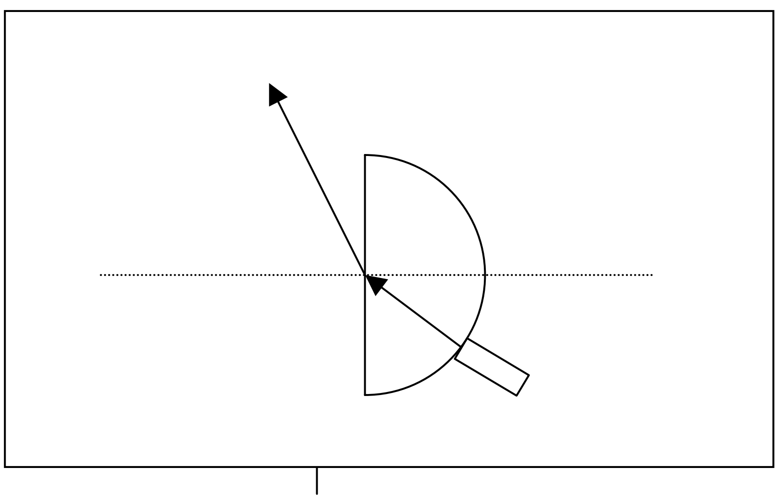
The purpose of this activity is to observe total internal reflection

Materials

Ray box, semi-circular plastic water tank, semi-circular solid plastic, protractor.

Procedure

Set up the paper and semi-circular tank as before, but have the ray box on the opposite side of the tank.
Orient the ray box so that the ray strikes the center point, and trace the refracted ray.
Move the ray box so that the ray strikes the center point, but with a greater angle of incidence. Trace the refracted ray.
Keep doing this until the angle of refraction is 90°. The corresponding angle of incidence is the *critical angle* of water.
Increase the angle of incidence and observe what happens to the light ray.
Repeat with the plastic.
Record the angles of incidence and refraction



Water to air		Plastic to air	
Angle of incidence	Angle of refraction	Angle of incidence	Angle of refraction

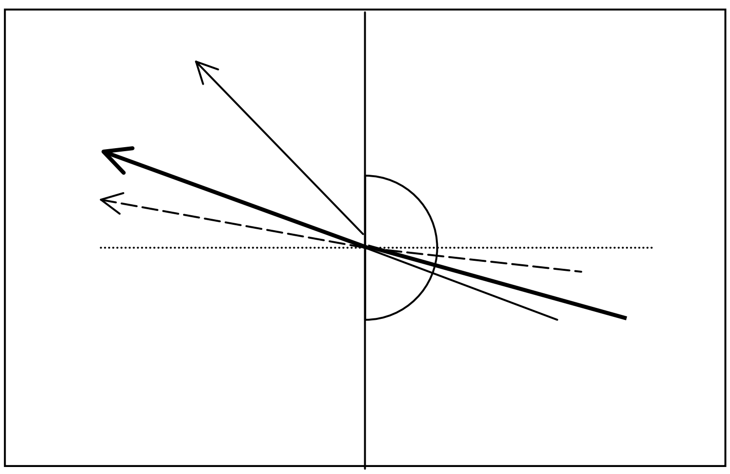
Labs 6 and 7
Teachers Notes

Materials

Most Physics departments will have the semi-circular water tanks. If you don't have the semi-circular plastic blocks you can use rectangular ones.

Procedure and Observations

When you set up the ray box try to make the light ray as narrow as possible, and make sure the ray falls along the paper (older ray boxes tend to warp on the bottom, and the ray sometimes aims up).
The best way to trace the refracted ray is to locate the spot where the ray leaves the water (or plastic)
Use 3-4 angles, but use small angles, 10, 18, 28, 35 degrees. The larger the angle, the more difficult it is to locate the refracted ray.
The diagram should look something like the following sketch.



You should observe that the angle of incidence is always larger than the angle of refraction.
You should also observe that the angles of refraction for water are larger than the corresponding angles of refraction for the plastic.

Here is a set of "perfect" results of a light ray moving from air to water.

Angle i	10°	20°	30°	40°	50°	60°	70°	80°
Angle r	7.5°	15°	22°	29°	35°	41°	45°	48°

When you calculate the ratio i/r you observe that initially the ratios are similar, but as the angles increase the ratio also increases.

When you find the ratios of *sin i/ sin r* though, the observation is that the ratio remains at a constant value of 1.33, the index of refraction of water.
The index of refraction for most plastic materials should be close to 1.50.

Conclusions

This experiment leads to several very important conclusions.
First is the fact that when light travels from one material into another, it changes direction.
Secondly the amount of bending depends on the materials involved.

This ability to bend light depends on a characteristic of a material know as its *index of refraction.* The symbol for index of refraction is the small letter "n"
The *index of refraction* for water is 1.33, for plastic 1.50.

The mathematical formula that describes this is *The Law of Refraction* is

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where the 1 refers to the first material, 2 to the second.

This formula is important when the topic of *total internal reflection*, and *critical angles* is covered
For total internal reflection to occur the light ray must start in the *optically denser* material (the one with the higher index of refraction). As a light ray moves from the denser (e.g., water) into the *less dense material* (e.g. air) the ray will bend away from the normal. As the angle of incidence increases so will the angle of refraction. Therefore the angle of refraction will reach 90° before the angle of incidence. The angle of incidence at which the light ray has an angle of refraction of 90° is the *critical angle*. If the angle of incidence is greater than the critical angle the light ray reflects back into the material rather than moving into air. For all practical purposes the surface between the materials becomes a mirror.
This is the principle of light transmission along *optic fibres.* Optic fibres are made of materials that have a high index of refraction, and therefore a small critical angle. So a light ray that enters an optic fibre bounces from interior surface to interior surface until it reaches the other end of the fibre.
The advantages of optic fibres are that they are cheaper than metal wires that carry electric signals, they do not corrode as easily, and they can carry much more information (10 000 times as much) as electric wires.

Lab 8 Ohm's Law

Purpose

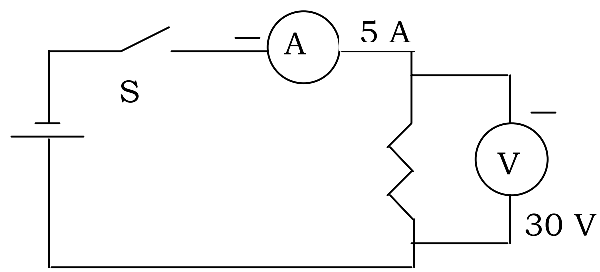
The purpose of this demonstration is to illustrate the relation between current, and electric potential energy difference.

Materials

Switch, resistance board, power supply (batteries), voltmeter, ammeter, six wires for connections

Procedure

Set up the diagram as shown below.



Part 1

Use the 1st and last terminal on the resistance board as the load.

Part 2

Use the 5th and last terminal on the resistance board as the load.

For each part use four different settings on the power supply (battery) and record the readings on the meters

Observations

PART 1		PART 2	
Voltage (V)	Current (A)	Voltage (V)	Current (A)

Questions

What happens to the current when the voltage is increased?
What is the relationship between the voltage and the current in each of the two parts?

Lab 8 Ohm's Law
Teachers Notes

When you do this experiment use the resistance boards which are found in all Physics departments. They are 5 wire coils mounted on a rectangular plastic board. The characteristics for each coil are on the board. For example the first coil has a length of 10 m, is made of copper, and has a #22 thickness. The diagram shows the connections that should be made so that the meter readings are positive.
If you do not have a variable power supply, you can increase the voltage by using multiple batteries.
It is important to note that **ammeters** are **always** connected in **series**, and **voltmeters** are **always** connected in **parallel**.

Georg Ohm discovered one of the basic laws for electricity:

$$R=V/I$$

where
V = electric potential energy difference (Volts)
I = current (Amperes)
R = resistance (Ohms)

If it is solved for I, then I=V/R. Current is proportional to voltage; therefore, increasing the voltage increases the current. Current is inversely proportional to resistance; therefore, as resistance increases, current decreases.

The battery provides voltage, an electric pressure that pushes electrons through the wire and lamp. Electrons flow easily through the wire, but with difficulty through the resistor, which has resistance to electron flow. Current squeezed through it shakes the atoms so vigorously that the resistor begins to heat.

It is these three quantities of electricity that work in the transmission of data through many electrical devices. The electrical energy has been converted to, or from, another form of energy, for example, light or sound.

<u>Research Assignment</u>

Whether a substance is classified as a conductor or an insulator depends on how tightly the atoms of the substance hold their electrons. Some materials are neither a good conductor nor good insulator, and fall in the middle of the range of electrical resistivity. These materials can be made to behave sometimes as an insulator and sometimes as conductors, and are called ***semiconductors***.

Part 1:
You are required to research the characteristics and applications of semiconductors.

Determine one element or material that is classified as a semiconductor.
Discuss the properties of this element or material, both physical and chemical.
Provide a diagram of the element or material.
Discuss the applications of this material or element. How and where is the semiconductor used? How does its usage affect our everyday life?
How does this semiconductor benefit or enhance communication and technology?
Any other interesting or pertinent information.

The presentation of your research should be creative and interesting for the viewer.

Some examples:
poster presentation
video presentation
report
oral presentation
drama presentation
etc

Part 2
You are to find a newspaper or magazine article that discusses the pros and cons of your particular semiconductor. You are required to summarize the information from the article and hand in both the article and summary.

Part 3

You are to find a communication device that uses your semiconductor and either accompany your presentation with the device itself, or with a picture or model of the device.

<u>Rubric for the Research Assignment: Semiconductors</u>

Criteria	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Planning	Shows a limited understanding of the task	Shows some understanding of the task	Shows considerabl understanding of the task	Shows a thorough understanding of the task
Properties of the Material/Element	States 1or 2 properties, briefly	States 4 to 6 properties, briefly	States 3 to 4 properties, and describes them in detail	States more than 5 properties, and describes them in de
Presentation	Presentation achieves limited results	Presentation partially achieves intended results	Presentation achieves the intended results	Presentation exceeds the intended results
Article summary	Reflects a limited understanding of the article	Reflects a partial understanding of the article	Reflects a complete, or nearly complete understanding of the article	Reflects an insightful understan of the article
Usage of this device	Shows limited understanding of the application of the device	Shows some understanding of the application the device	Shows a clear understanding of the application of the device	Shows a clear understanding of the application of the device, and indicates future applications, or improvements
Grammar and Spelling	Many spelling and grammatical errors	Some spelling and grammatical errors	Few spelling and grammatical errors	No more than 2 spelling or grammati errors

Lab 9 Electromagnets

Purpose
To examine the characteristics of simple electromagnets

Materials
Two or three batteries, bell wire, iron filings, large piece of cardboard, long nail, paper clips

Procedure
Activity 1:

1 Remove about 2-3 cm of insulation from the end of the wire.
2 Wrap the wire tightly around a pencil to form a coil.
3 Sprinkle iron fillings on the cardboard.
4 Place the wire coil on the cardboard, in the middle of the iron filings.
5 Connect one of the wires to the negative end of the batteries in series, and connect the other end to the positive.
6 Keep the electricity going, and tap the cardboard gently, until you see a pattern.
7 Draw this pattern onto a piece of paper.

Activity 2:

1 Wrap about 20 turns of wire around the nail.
2 Pull the nail out.
3 Try to lift the paper clips with the coil.
4 Record your observations. (If you can lift one)
5. Next, slip the nail back into the 20 turns of wire and connect the wires to the battery.
6. Lift paper clips with the end of the nail. (You will lift several)
7. Record your observations.
8. Next wrap 50 turns of wire around the nail (you can start a second layer, but make sure the winding is in the same direction).
9. Reconnect the electromagnet and lift paper clips. (You will be able to lift many more paper clips than before).
10. Record your observations.
11. Finally connect a second battery in series with the first.
12. Turn on the electromagnet and lift paper clips. (You will lift even more paper clips)
13. Record your observations.
14. Using the observations make conclusions with regard to the characteristics of an electromagnet.

Lab 9 Electromagnets
Teachers Notes

Purpose

The purpose of this lab is to introduce the students to the relationship between magnetism and electricity. Also to determine what factors affect the strength of electromagnets.

Electromagnets are used in many communication devices such as microphones and speakers etc.

Introduction

It is important that the insulation from the wire is removed, for activity 1, before the lesson. You need to inform the students that they disconnect the wires from the battery when moving to each new step. It would be beneficial if you could step up stations prior to the lesson.

Observations

The key observations are:
The iron filings generate a pattern that represents the magnetic field around the wire.
For activity 2, without the nail no paper clips are lifted.
With the nail several paper clips are lifted.
With increased turns more paper clips are lifted.
With an increased number of paper clips even more paper clips are lifted.

Summing up

This is a simple activity for the students to become reacquainted with working with simple circuit set-ups. This can prepare them for the construction activity to follow.

Appendix A Supplemental Lab on Radio Waves

This activity can also be modified to focus the radio waves from a local AM radio station to the receiving radio. The location of the transmission antennae can be found by calling the radio station in order to orient the umbrella/wok focusing dish properly. In addition, moving the focusing dish back slowly from an initial close position and monitoring the volume level (volume dial set medium low) can provide information about the wavelength of the radio-waves from the AM radio station.

http://www.pbs.org/safarchive/4_class/45_pguides/pguide_901/4491_dish.html

Science in Paradise: Big Dish

Nestled in the hills of Puerto Rico, the Arecibo Observatory tunes in to the universe, searching for signals from distant space, using the world's largest radio telescope. Arecibo searches for pulsars and distant galaxies, listening for a signal that may indicate the presence of intelligent life elsewhere. The telescope also monitors the presence of asteroids, especially any that may be headed toward Earth.

ACTIVITY 1: MODEL A BIG DISH

Arecibo is a huge dish 305 meters in diameter, shaped like part of a sphere and set in an ancient limestone crater. Most of Arecibo's work is radio astronomy -- listening to and amplifying radio waves, enabling astronomers to discover stars and galaxies at the edges of the universe. A recent upgrade makes Arecibo ten times more sensitive than it used to be. In addition, its new, more powerful radar-emitting device can detect and create images of asteroids -- especially those that might be headed toward Earth.

Arecibo and other radio telescopes are reflecting dishes that use curved surfaces to collect and reflect radio waves. If you have a satellite dish on your house or in your backyard, you are using a smaller version of a reflecting dish. Arecibo's "antenna dish" (the curved surface) collects and reflects signals. When radio waves strike the surface, they are reflected back through the focus (the dome), which concentrates the signals.

In this activity, you'll experiment with a curved reflecting dish that will work like the Arecibo detector. Then you'll use your model to detect electromagnetic waves.

MATERIALS

Radio (not a Walkman)

Appliance that produces radio static ("noise")

Cooking wok

Aluminium foil

NOTE: Appliances that produce static include motorized toys, blenders, small electrical motors, grinders, microwaves, etc. Experiment with different receptors and static producers. If using a blender, mixer or microwave, remember to boil or blend water; do not run the appliance empty. You can use a digital or analog radio or a small TV and do not necessarily need a radio with an antenna.

PROCEDURE

1. Line the bowl of the wok with several layers of heavy-duty aluminium foil. Smooth the foil. Carefully remove the foil so it keeps the shape of the wok. This is your model of the Arecibo dish.

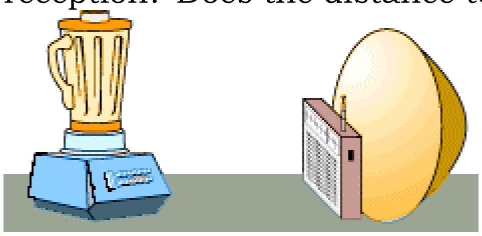
2. If your radio has an external antenna, push it in to its shortest length.

3. Switch on the radio. The instructor or another student should switch on a nearby appliance that produces radio static ("noise").

4. While the noisy appliance is running, move the radio next to the appliance and tune the radio to the static. (Note the difference between the background static and the static produced by the appliance; background static is more random, but the appliance static usually has a "pulse.")

5. When you have tuned in the static so it's distinct, slowly separate the devices until the static created by the appliance is no longer broadcast by the radio. You'll have to walk about 15 to 20 feet away from the appliance.

Hold the reflecting foil dish behind the radio so its bowl side faces the contracted antenna and aims directly at the appliance. How does the dish affect the static? (The foil dish should create static again.) Aim the bowl in different directions. How does the direction of the bowl effect reception? Does the distance to the antenna affect the static?



6. The wok is also spherical and can be used as a reflecting dish. Its smooth surface will concentrate the waves better than the foil, which, if it's crinkled, might reflect the waves in random directions. Try using the wok instead of the foil dish. How does the change affect reception?

What's going on here? The wok or foil dish is comparable to the reflecting dish at Arecibo. Signals that reach the Arecibo dish are collected and reflected back to the dome; signals reaching the tin foil dish are reflected and concentrated at the radio or its antenna.

EXTENSIONS

How might an umbrella lined with aluminium foil affect the detection of radio static? Make a prediction. Construct a reflecting antenna dish with aluminium foil and an umbrella. Test your detector. Can you detect local stations? Make a guess. Then, check it out!

Ordinary radio telescopes are constructed more in the shape of a parabola. Look for other examples of parabolas -- from flashlights to car headlights. How might a parabola reflect radio waves?

Appendix B Demonstration Measuring Resistance

Purpose

To demonstrate the difference between conductors and insulators.

Materials

Rubber stopper, glass tube (50 mm, diameter), large marbles, small marbles, cardboard disc
(with holes and without holes), can

Procedure

Construct an apparatus to illustrate the concept of the conductor versus the insulator. The apparatus is made of a plastic tube about 50 mm in diameter, 20 - 40 cm long, and open at both ends (this can be obtained from your physics department, it is the kind used to determine the wavelengths for a tuning fork). The bottom is sealed using a cardboard disc with holes, the size of the smallest marble, punched in it with a paper punch and secured by some tape. The tube is then filled with marbles, 15 - 20 mm in diameter, which represent the "atoms" in the conductor. Once these are packed, pour small (1 - 3 mm diameter) marbles "electrons" in from the top. Once the tube is fully packed , the "electrons" can be gently forced into the system by inserting a rubber stopper into the top of the tube. This causes the "electrons" small marbles to flow out the other end. Where they will be captured in the can. This shows current flow when there is little resistance.
This can be repeated using a cardboard disc without holes to demonstrate the lack of electron flow in an insulator.

Explanation:

The resistance to the passage of electric current is measured with the ohmmeter. Insulators oppose the flow of electric current and have a high resistance. Conductors have a low resistance. Factors that affect the resistance of wires are:

1. The thickness of the wire.
2. The length of the wire.
3. The material of the wire.
4. The temperature of the wire.

Wires are made from several metals. **Aluminum** and **copper** are good conductors because they have a low resistance.
Toasters and electric heaters are made with wires of **nichrome**, a metal that has a higher resistance than copper and aluminum and gets hot when electric current goes through it.
Tungsten also has a high electrical resistance and is used as the filament for light bulbs. It gets so hot that it glows.

Appendix C WebLinks

The following annotated list includes online activities which require an internet connection and an up-to-date browser. Many of these can be downloaded/copied onto a floppy disk or local hard drive to enable student access where computers are available but without an internet connection.

PHYSICS SIMULATIONS AND APPLETS FOR COMMUNICATIONS UNIT

Oscilloscope
Basic Function of an Oscilloscope
site location:
http://www.phy.ntnu.edu.tw/java/oscilloscope/oscilloscope.html
This java applet shows the basic functions of an oscilloscope. The oscilloscope is an electronic instrument widely used in making electrical measurements. The main component of the oscilloscope is the cathode ray tube (CRT). The CRT is a vacuum tube in which electrons are accelerated and deflected under the influence of electric field. The electrons are deflected in various directions by two sets of plate placed at right angle to each other in the neck of the tube. Signal for the horizontal deflection plate (X-axis) is generated by the scope.
See also:
http://plabpc.csustan.edu/general/Tutorials/EM/Oscilloscope/Oscilloscope.htm

Pendulum
pendulum demo
site location: http://www.fladownloads.com/swf/pendulum.swf
shows the way that the swing of a pendulum (speed and frequency) changes by altering the length of the string. To use: move the disc thing up and down along the string. click the top black dot at the top to start the pendulum

Reflection and Refraction of Waves
Topic: Refraction and Reflection
http://physicsweb.org/vlab/
This shows the reflection and refraction of both light and sound.

Ripple Effect
Topic: Waves
http://www.falstad.com/mathphysics.html (click on Ripple Tank 2-D Waves)

This shows dispersion of waves from specific sources. Notice you can changes where the sources are. You can also experience different effects, i.e Doppler Effect and Sonic Booms. See how you can manipulate the waves.

Optic Bench
Topic: Optics
http://webphysics.davidson.edu/Applets/optics4/default.html
Customizable optic bench, it includes lenses, mirrors apertures and configurable light beams.

Ripples in Water
Topic: Constructive and destructive interference
http://galileo.phys.virginia.edu/~snp9b/java/Ripple.html

Nanoguitar
Guitar String frequency
http://www.aip.org/physnews/graphics/html/nanotar.htm
Shows worlds smallest guitar

Frequencies
http://www.explorescience.com/activities/Activity_page.cfm?ActivityID=44
Listen!

Franklin's Kite
Topic: electricity
http://www.mos.org/sln/toe/kite.mov
http://www.ushistory.org/franklin/kite/index.htm
One of Benjamin Franklin's most remarkable areas of discovery is electricity. This demo shows his famous experiment using a key and a kite during a thunderstorm, which was carried out to prove that lightning bolts, are actually powerful electrical currents.

Reflection and Refraction of Waves
Topic: Refraction and Reflection of Waves
http://home.a-city.de/walter.fendt/phe/huygenspr.htm
A plane approaches a medium and reflects and refracts sound at different speeds because the two mediums have different indexes of refraction.

Electromagnetic Induction
Topic: Electric Guitar Pickups
http://micro.magnet.fsu.edu/electromag/java/lenzlaw
Electric Guitar Pickup Detail Picture
http://www.europhysicsnews.com/full/10/article2/article2.html

Polarizers effect
Topic: Polarizers
http://lectureonline.cl.msu.edu/~mmp/kap24/polarizers/Polarizer.htm
This demo demonstrates how light travels through polarizers. It takes a laser and shoots it through 1 to 3 polarizers. Then the amount of light received in the other end is recorded.

Smart Pendulum
Gravitational Forces
http://odin.prohosting.com/~evgenik1/pend.htm
Once you are on the web page click on the Java applet if it does not come up This Java applet shows how gravity can affect an object hanging freely. You can set the Gravity and Viscosity to different numbers and see how this affects the speed of an oscillation.

Tranverse Stationary Wave
Topic: Waves and Sound
Webpage: http://www.ngsir.netfirms.com/englishhtm/TwaveStatA.htm
This applet demonstrates a standing wave with either two fixed ends or one fixed end with one free end. The interference and reflection of waves from the two ends form this type of wave. It shows the number of loops and nodes (result of destructive interference) present from the fundamental frequency (lowest frequency) to the 6th harmonic (higher frequencies) of a vibrating string. Also, it shows us the specific frequency of vibration with the corresponding wavelength. The amplitude can be adjusted from larger to smaller but if you go too small, a = 0 and it will be just a straight horizontal line.

Ng, C.K. (2002). Physics Java Applets. [On-line]. Available: http://www.ngsir.netfirms.com/englishVersion.htm.

Voltage
Topic: Electricity
Webpage: http://jersey.uoregon.edu/vlab/Voltage/
This applet allows users to test different power sources and add the total resistance needed to make the bulb light up. Too many resistors won't light up the bulb and not enough resistors will blow up the bulb if the voltage applied is high. You are able to experiment with different power source voltages, and different resistance values. This demo explains Ohm's Law and the relationships between the parts of a circuit.

Interface Optics
Topic: Light and Geometric Optics
Webpage: http://www.msu.edu/user/brechtjo/physics/
This applet shows the difference between reflection, refraction, and diffraction. It demonstrates the light passing through a medium and the direction the light would take.

Demo: Refraction of Light
Topic: Light
Address:
http://micro.magnet.fsu.edu/primer/java/refraction/index.html
What is it about? Basically, this demonstration shows us how light waves move throughout different mediums and the different angles (ie. incident angle) at which the light can refract. Also, the wavelength, through colour, can be illustrated.

Standing waves, medium fixed at both ends
http://id.mind.net/~zona/mstm/physics/waves/standingWaves/standingWaves1/StandingWaves1.html
This is a demo that shows the standing wave patterns that are made on a medium such as this violin. The medium is held at both ends which causes it to be motionless at the very ends.

Locating Images by Ray Tracing
Lens and Mirrors
http://webphysics.ph.msstate.edu/jc/library/22-6/index.html
This applets shows both converging and diverging lens and mirrors. It shows where the image is when the object is shifted around the screen. The location of the object and the focus point can be adjusted. It shows the rays used to find the image.
Electrical Motors

Image Formation by a Converging Lens
Converging Lens
http://www.lightlink.com/sergey/java/java/clens/index.html
This applet shows the location of the object's image when you move the object to different locations on the screen for a converging lens. It shows you the location of the focus point, and numerical answers to where the image is compared to the object. It also shows the rays used to find the image.
Image Formation by a Diverging Lens
Diverging Lens
http://www.lightlink.com/sergey/java/java/dlens/index.html
This applet shows the location of the object's image when the object is at different locations for a diverging lens. It provides numerical answers to where the image is compared to the object. This also shows the rays used to find the image.

Interference of Two Sinusoidal Waveforms
Adding Transverse Waves
Topic: Waves
http://surendranath.tripod.com/Twave/Twave02.html
A great demo showing transverse wave disturbances. It shows how they react when they meet. Allows changeable amplitude, in or out of phase waves. Wave positions can be slowed down or shown at the various positions during the adding of waves.

Lenz's Law
Topic: Electromagnetism
http://micro.magnet.fsu.edu/electromag/java/lenzlaw/index.html
A small demonstration of how Lenz's Law works. A bar magnet is moved inside a solenoid to create current. Also shows direction of current flow.

Focal Length Demo
Topic: Lenses
http://homepage.tinet.ie/~juniorcert/# (click on enter and click on lenses. Try the other demos too!!!)
This demo allows the user to change the focal length to see how the eye sees the letter "a" when the focal length is changed. There are also many other activities to try for refraction and reflection.

Electric Motor Demo
Topic: Electricity
http://home.a-city.de/walter.fendt/phe/electricmotor.htm
This demo shows in very simple terms the way in which a split ring commutator allows DC current to obey Lenz law. You can also view the magnetic field, the Lorentz force and the current direction.

Tranverse Stationary Wave
Topic: Waves and Sound
Webpage: http://www.ngsir.netfirms.com/englishhtm/TwaveStatA.htm
This applet demonstrates a standing wave with either two fixed ends or one fixed end with one free end. The interference and reflection of waves from the two ends form this type of wave. It shows the number of loops and nodes (result of destructive interference) present from the fundamental frequency (lowest frequency) to the 6th harmonic (higher frequencies) of a vibrating string. Also, it shows us the specific frequency of vibration with the corresponding wavelength. The amplitude can be adjusted from larger to smaller but if you go too small, a = 0 and it will be just a straight horizontal line.

Ng, C.K. (2002). Physics Java Applets. [On-line]. Available: http://www.ngsir.netfirms.com/englishVersion.htm.
File Name: Transverse Stationary Wave

http://www.ngsir.netfirms.com/englishhtm/TwaveStatA.htm

Voltage
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Webpage: http://jersey.uoregon.edu/vlab/Voltage/
This applet allows users to test different power sources and add the total resistance needed to make the bulb light up. Too many resistors won't light up the bulb and not enough resistors will blow up the bulb if the voltage applied is high. You are able to experiment with different power source voltages, and different resistance values. This demo explains Ohm's Law and the relationships between the parts of a circuit.
Note: This site also has some excellent projectile motion exercises (cannon shooting monkey).
Bothun, Greg. Welcome to the Voltage Circuit Simulator.
[On-line]. Available: http://jersey.uoregon.edu
/vlab/Voltage/.

Interface Optics
Topic: Light and Geometric Optics
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What is it about? Basically, this demonstration shows us how light waves move throughout different mediums and the different angles (i.e. incident angle) at which the light can refract. Also, the wavelength, through colour, can be illustrated.

String Waves
Standing waves, medium fixed at both ends
http://id.mind.net/~zona/mstm/physics/waves/standingWaves/standingWaves1/StandingWaves1.html
This is a demo that shows the standing wave patterns that are made on a medium such as this violin. The medium is held at both ends which causes it to be motionless at the very ends.

Locating Images by Ray Tracing
Lens and Mirrors
http://webphysics.ph.msstate.edu/jc/library/22-6/index.html
This applets shows both converging and diverging lens and mirrors. It shows where the image is when the object is shifted around the screen. The location of the object and the focus point can be adjusted. It shows the rays used to find the image.

Electrical Motors
http://webphysics.ph.msstate.edu/jc/library/20-3/index.html
This applet shows a motor. It shows the direction of the positive flow of electrons, and the direction of the magnetic field. You are able to adjust the frequency and the direction of the motor.

Interference of Two Sinusoidal Waveforms Waves
http://webphysics.ph.msstate.edu/jc/library/15-11/index.html
This applet shows what happens when two waves interfere with each other. It supplies another graph that shows the sum of both waves.

Image Formation by a Converging Lens Converging Lens
http://www.lightlink.com/sergey/java/java/clens/index.html
This applet shows the location of the object's image when you move the object to different locations on the screen for a converging lens. It shows you the location of the focus point, and numerical answers to where the image is compared to the object. It also shows the rays used to find the image.

Image Formation by a Diverging Lens
Diverging Lens
http://www.lightlink.com/sergey/java/java/dlens/index.html
This applet shows the location of the object's image when the object is at different locations for a diverging lens. It provides numerical answers to where the image is compared to the object. This also shows the rays used to find the image.

Appendix D Multiple Choice Question Bank

1-24 Sound and Waves 25-62 Electricity, magnetism and light

1. The speed of waves in a stretched string (or Slinky) depends on
   (a) the tension in the string. (b) the amplitude of the waves.
   (c) the wavelength of the waves. (d) the acceleration of gravity.

2. The higher the frequency of a sound wave,
   (a) the lower its speed. (b) the shorter its wavelength.
   (c) the greater its amplitude. (d) the longer its period.

3. Of the following properties of a wave, the one that is independent of the others is its
   (a) amplitude. (b) speed. (c) wavelength. (d) frequency.

4. Waves transmit _____ from one place to another
   (a) mass. (b) amplitude. (c) wavelength. (d) energy.

5. In a longitudinal/compression wave, the individual particles of the medium
   (a) move in circles. (b) move perpendicular to the direction of travel.
   (c) move in ellipses (d) move parallel to the direction of travel.

6. Two waves meet at a time when one has the instantaneous amplitude A and the other has the instantaneous amplitude B. Their combined amplitude at this time is
   (a) A + B. (but if B is negative the result might be 0)
   (b) A - B. (c) between A + B and A - B. (d) indeterminate.

7. Sound waves are
   (a) longitudinal. (b) transverse.
   (c) partly longitudinal and partly transverse.
   (d) not actually waves at all, they are projectiles from Marilyn Manson's mouth.

8. Sound travels fastest in
   (a) cool air. (b) water. (c) warm air. (d) vacuum
   (e) none of the above, the speed of sound is constant.

9. Sound waves do not travel through
   (a) solids. (b) gases. (c) liquids. (d) plasma matter (interior of the sun) (e) a vacuum.

10. The frequency of a sound wave determines its
(a) pitch. (b) loudness (c) overtones. (d) resonance.

11. The amplitude of a sound wave determines its
(a) pitch. (b) loudness (c) overtones. (d) resonance.

12. A pure musical tone causes a thin wooden panel to vibrate. This is an example of
(a) an overtone. (b) harmonics. (c) resonance.
(d) interference. (e) none of the above.

13. A loud boom is heard after an airplane has passed overhead. This means that the airplane
(a) is accelerating. (b) is climbing.
(c) is traveling faster than 400 m/s.
(d) is traveling faster than the speed of light.

14. A space craft speeding away from Earth sends out signals of a certain frequency. The signals that are received on the earth:
(a) have a lower speed. (b) have a lower frequency.
(c) have a higher speed . (d) have a higher frequency

15. Sound waves whose frequency is 300 Hz have a **speed** relative to sound waves in the same medium whose frequency is 600 Hz that is:
(a) half as great. (b) the same. (c) twice as great.
(d) four times as great.

16. If the frequency of sound waves gets smaller by a factor of two then the wavelength is:
(a) half as great. (b) the same. (c) twice as great.
(d) four times as great.

17. How many times more intense is a 90 dB sound than a 40-dB sound?
(a) 100 000 (b) 50 (c) 500 (d) 2.25

18. Radio amateurs are permitted to communicate on the '10-meter band.' What frequency of radio waves corresponds to this wavelength? (The speed of radio waves is 3×10^8 m/s)
(a) 3.3×10^6 Hz (b) 3.0×10^7 Hz (c) 3.3×10^8 Hz (d) 3.0×10^9 Hz

19. Two tuning forks of frequencies 3l0 Hz and 3l6 Hz vibrate simultaneously. The number of times the resulting sound pulsates per second is
(a) 0. (b) 6. (c) 313. (d) 626.

20. A radio station broadcasts at a frequency of 660 kHz. The wavelength of these waves is
(a) 2.2 mm (b) 455 m (c) 4.55 km (d) 1.98 x 10^2 m.

21. Waves in a lake are 5 m in length and pass an anchored boat 1.25 s apart. The speed of the waves is
(a) 0.25 m/s. (b) 4 m/s. (c) 6.25 m/s.
(d) impossible to find from the information given.

22. A boat at anchor is rocked by waves whose crests are 40 m apart and whose speed is 10 m/s. These waves reach the boat once every
(a) 400 s. (b) 30 s. (c) 4 s. (d) 0.25 s.

23. True (A) or False (B). A pendulum which moves 8 m in one cycle has an amplitude of 4 m.

24. True (A) or False (B). You can measure the distance to lightning by the time gap between the flash and the "clap" of the thunder.

25. To attract a negative vinyl strip, an object could be
(a) positive (b) negative (c) neutral
(d) positive or neutral (e) negative or neutral

26. To attract both a negative strip and a positive strip, an object must be
(a) positive (b) negative (c) neutral
(d) positive or neutral (e) negative or neutral

27. A negatively charged rod is brought close to a pith ball. The pith ball moves toward the rod but does not touch it. We can be sure that the pith ball is
(a) negatively charged only (b) not negatively charged
(c) positively charged only (d) neutral only
(e) neutral or negatively charge

28. The neutral particles contained in the nucleus of an atom are called
(a) alpha particles (b) electrons (c) ions
(d) neutrons (e) protons

29. Which of the following is classified as a good insulator?
(a) an aluminum wire (b) a copper wire (c) gold
(d) hard rubber (e) any electrolyte (acid in a wet cell)

30. A neutral object

(a) has zero electrons

(b) has zero protons

(c) is composed only of neutrons

(d) has a balanced number of electrons and protons

(e) contains prions

31. An uncharged pith ball is electrically
(a) attracted by another uncharged pith ball
(b) attracted by a charged glass rod
(c) repelled by a charged ebonite rod
(d) repelled by a charged glass rod
(e) unaffected by a charged object

32. If an object attracts a positive charged pith ball and repels a negatively charged pith ball, then the objects charge is:
(a) neutral (b) negative (c) positive
(d) neutral or negative (e) neutral or positive

33. In a lightening storm you would be safest:
(a) in a car (b) under a tree
(c) on a hill (d) in the middle of a field
(e) holding a metal pole

34. When a positively charged object is grounded, electrons move from:
(a) around the object
(b) back to their original location on the object
(c) the ground to the object(d) the object to the ground

35. Substances that can easily be electrified by friction, or rubbing, are all
(a) metals (b) conductors (c) insulators (like fur, glass…)
(d) expensive (e) black and dull

36. The colour commonly given to the negative terminal of an electrical energy source is
(a) red (b) blue (c) green (d) white (e) black

37. In a cell the electrons come out of the terminal which is
(a) positive (b) close to the switch (c) in series
(d) nearest the load (e) negative

38. A 1.2 V dry cell is the energy source for a circuit. The circuit has two identical lamps in parallel. If a *third identical lamp is added in parallel*
(a) the first two get dimmer (b) the first two go out
(c) the third lamp is dimmer (d) all lamps get dimmer
(e) all lamps glow equally bright

39. A 1.2 V dry cell is the energy source for a circuit. The circuit has two identical lamps in series.

If a *third identical lamp is added in series*

(a) the total voltage will increase
(b) the lamps will all differ in brightness
(c) the third lamp will burn out
(d) the three lamps will be dimmer
(e) the current through the circuit will increase

40. A 1.2 V dry cell is the energy source for a circuit. The circuit has two identical lamps in *series*.

If the second lamp burns out then

(a) the voltage of the dry cell will increase
(b) the dry cell will explode
(c) the first lamp will burn out,
(d) the first lamp will burn brighter
(e) the current through the circuit will increase

41. A short circuit is one which

(a) is missing a load
(b) is missing a conductor
(c) has a worn out cell
(d) has an open switch
(e) has a low current

42. The simple circuit contains all the following components but one. The one which is NOT part of a simple circuit is

(a) load (b) fuse (c) switch (d) conductors (e) energy source

43. The logical sequence of changes in energy which occur when a 1.2 V cell powers a circuit containing one small light bulb is

(a) electrical to chemical to heat and light
(b) solar to electrical to heat and light
(c) light and heat to electrical to chemical
(d) chemical to mechanical to electrical to heat and light
(e) chemical to electrical to light and heat

44. Potential difference (voltage) in an electric circuit is a measure of

(a) electron colour
(b) electron energy (J/C = 1 V)
(c) electron current
(d) resistance
(e) amount of elections

45. Amperes, in an electric circuit, is a measure of

(a) electron power (b) electron energy (c) electron current

(d) capacitance of electrons (e) resistance

46. The unit of electric potential difference is the
(a) ohm (b) watt (c) ampere (d) hertz (e) volt

47. The unit of electric current flow is the
(a) ohm (b) watt (c) ampere (d) hertz (e) volt

48. What would happen if you placed a larger fuse than the recommended one in a circuit?
(a) the wires in the circuit could overheat
(b) there might not be enough current
(c) there could be a short circuit
(e) the fuse could blow

49. A grounding wire protects the user if an appliance has a :
(a) short circuit (b) no off switch (c) small batteries (AA)
(d) light bulb

50. A wet cell is made of an electrolyte and
(a) one metal (b) two identical metals (c) two different metals
(d) acid

51. AC is a type of electrical current that
(a) reverses direction 60 times per second
(b) travels directly from the + to the –
(c) travels directly from the – to the +
(d) is used only in Europe

52. The domain theory is used to explain
(a) electromagnetism (b) static electricity (c) magnetism
(d) all of the above

53. An atom which contains 3 protons, 2 neutrons and 1 electron would have a net charge of:
(a) +3 (b) +2 (c) – 2 (d) – 1 (e) 0

54. A pair of 8 ohm resistors in series will have a total resistance of __ ohms
(a) 0 (b) 2 (c) 4 (d) 8 (e) none of the above

55. A pair of 8 ohm resistors in parallel will have a total resistance of __ ohms.
(a) 0 (b) 2 (c) 4 (d) 8 (e) none of the above

56. The magnetic field of a bar magnet most closely resembles that of a

(a) a straight current-carrying wire

(b) a stream of electrons moving parallel to one another

(c) a current carrying wire loop

(d) a horseshoe magnet

57. Benzene changes the speed of light (3×10^8 m/s in a vacuum) since it is more optically dense by factor of 1.5. The speed of light in benzene is ______ $\times 10^8$ m/s^2.
(a) 1.5 (b) 2 (c) 3 (d) 4.5

58. The bending of a wave when it passes from one medium to another is called:
(a) reflection (b) dispersion (c) refraction (d) transmission

59. The resistance of a wire depends on the following properties:
(a) length (b) temperature (c) cross-sectional area
(e) all the previous factors

60. A group of atoms whose magnetic fields all point in the same direction is called a:
(a) coil (b) molecule (c) rotor (d) core (e) domain

61. When a bar magnet is inserted into a coil at 20 cm/s, the maximum induced potential difference is 10 mV. What would be the induced potential difference if the same magnet were held in place (no movement)?
(a) 3.3 mW (b) 6.7 rnV (c) l0 mV (d) 30 mV
(e) none of the above

62. Pinhole cameras and the human eyeball both:
(a) are made of wood (b) invert the image
(c) reflect all light (d) reflect light
(e) work in the absence of all light