Apparatus Competition

2014 Summer Meeting of the American Association of Physics Teachers

AAPT PHYSICS EDUCATION SUMMER MEETING

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http://www.aapt.org/Programs/contests/apparatus.cfm

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Strobowave

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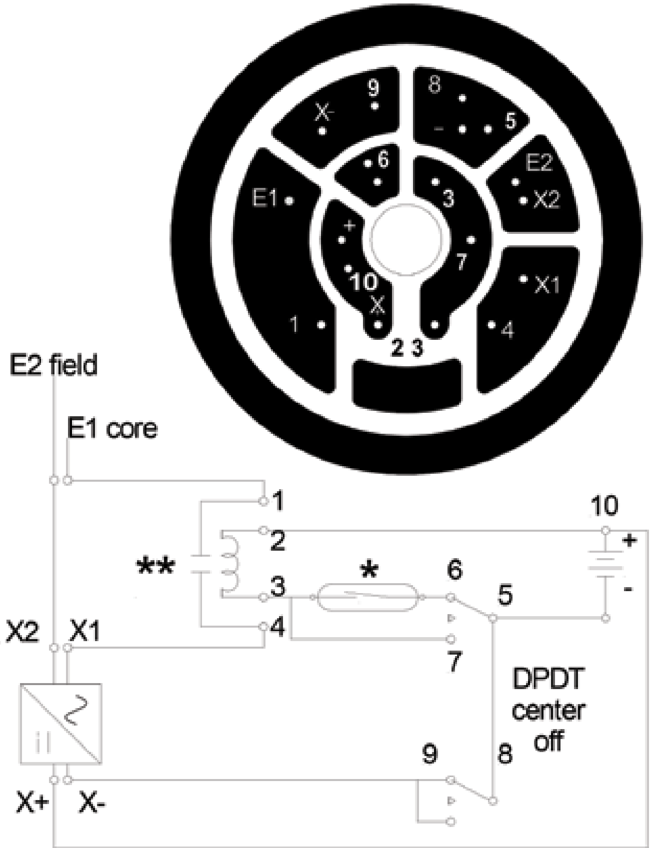
Abstract:
This apparatus affords an illuminated demonstration of standing waves. An internal circuit allows the wave to be strobed at a given phase allowing the waveform to be "frozen" in time as is usually done with an expensive stroboscope.

Construction:
The apparatus is constructed using: 5 m length of 5 mm diameter electroluminescent wire, a high-frequency 12VDC to 100+AC inverter, magnetic reed switch, 3 mm(D)X6 mm(L) neodymium magnet, DPDT mini toggle switch, 12 V mini relay, 8 AA battery holder, 8 1.5 V AA batteries, 12" piece of 1-1/2" SCH-40 PVC pipe and a PVC end cap. The construction diagram is in the following documents.

Use of apparatus:
The use of the apparatus is provided in the accompanying "Strobowave User Guide" which will be supplied with the apparatus. A multi-loop standing wave is established as done with a jump rope. The switch is moved to the constant-on position and the waveform is internally illuminated making the nodes and antinodes easily visible. When the switch is moved to the strobe position, the wave is illuminated only at a point a brief instant in the cycle, freezing the waveform in time.

SCHEMATIC CIRCUIT DIAGRAM

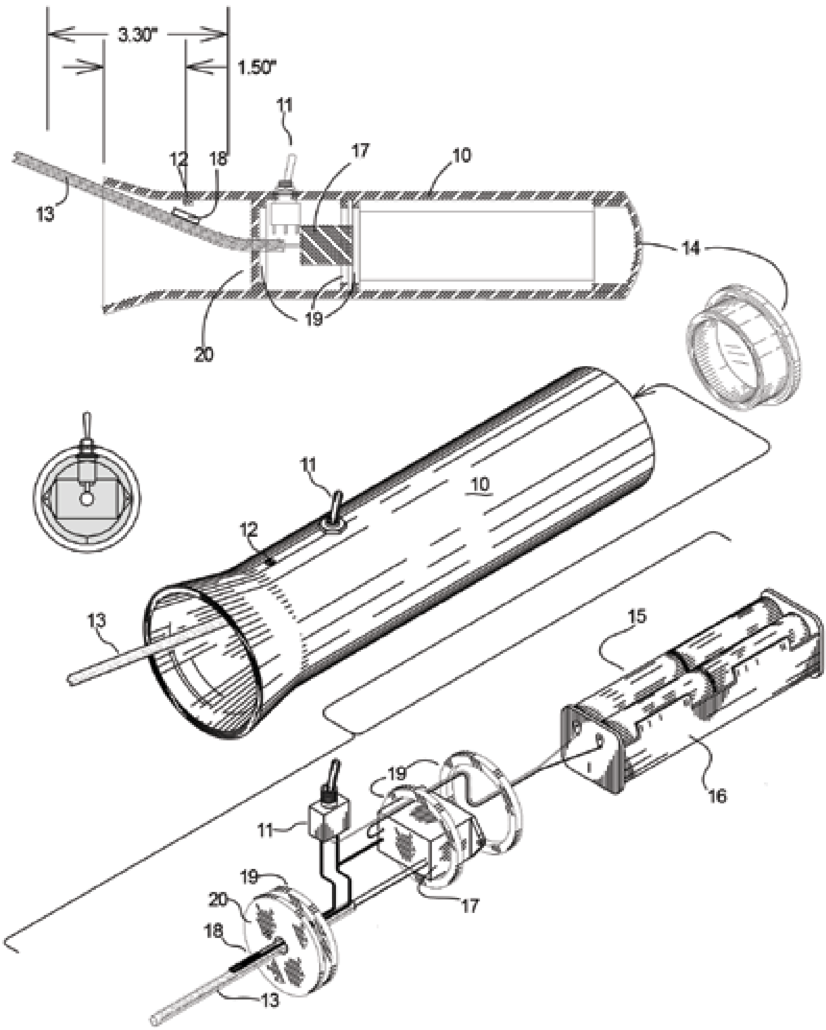
The circuit board is just a convenient way to organize the wires. It is not really necessary



*Mouser Part #: 816-9001-12-00 SIP Reed Relay

**Mouser Part #: 816-CT10-1030-G1 Magnetic / Reed Switches SPST Dry

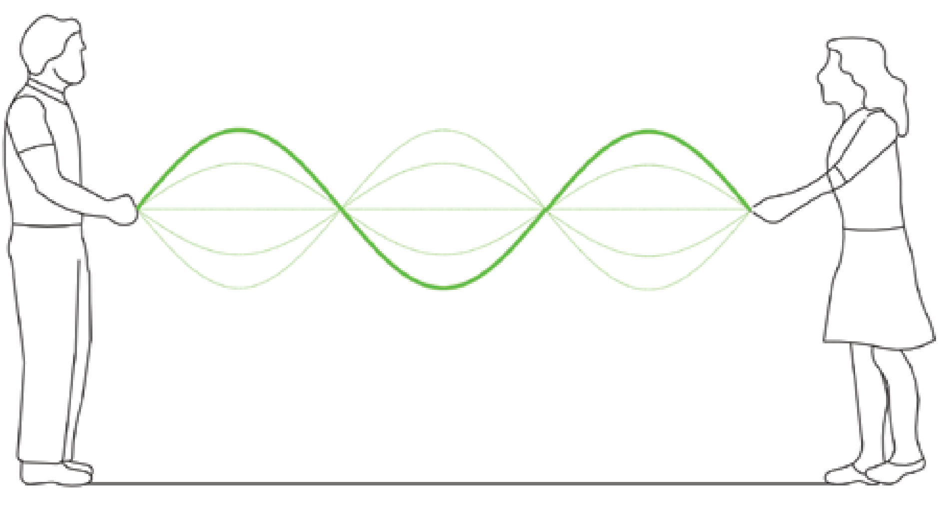
ASSEMBLY DIAGRAM



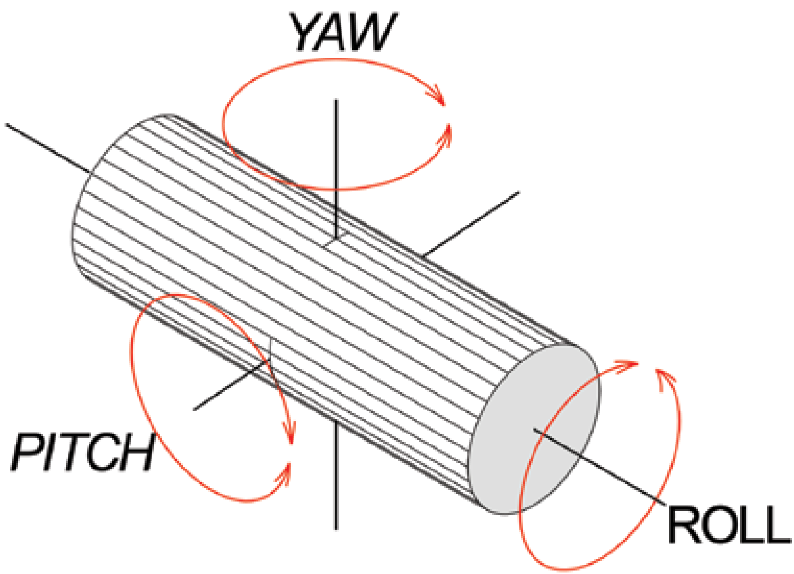
10 1-1/2" SCH-40 PVC flared on one end
11 DPDT mini center off toggle
12 3mm(D)X6mm(L) neodymium magnet
13 5mX5mm electroluminescent wire
14 PVC end cap
15 8 AA batteries
16 8 AA battery case
17 EL wire inverter
18 Magnetic reed switch
19. PVC split retainer ring
20 Circuit board

STROBOWAVE

USER GUIDE



- This is not a toy. It is a scientific apparatus but that's no reason it can't be fun!
- "Throw" large amplitude waves so that the wire makes contact with or is close to the flared end of the *Strobowave* housing.
- Changing the ***pitch*** of the *Strobowave* housing by tilting it up or down slightly will give some control over the length of time the wire is illuminated when in the strobe mode.
- ***Roll*** the *Strobowave* to bring the crest to the top when in the strobe mode.
- Do not play jump rope with the *Strobowave*.
- Do not strike objects with the *Strobowave* wire.
- Do not bend the *Strobowave* wire tighter than a 4 inch diameter circle.



USING THE STROBOWAVE

(The fun begins)

Dim the room lights, the darker the better. The switch positions are: ***center-off***, ***constant-on*** back and ***flashing-on*** in the forward position.

Have your assistant hold the tube of the Strobowave and move the switch back to the *constant-on* position. The wire lights as if by magic but it's not magic.

Everyone knows how to throw a jump rope so start with a simple standing wave, the jump rope wave. After the OOHs and AAHs, have your assistant move the switch to the *flashing-on* in the forward position and "freeze" the wave for several cycles.

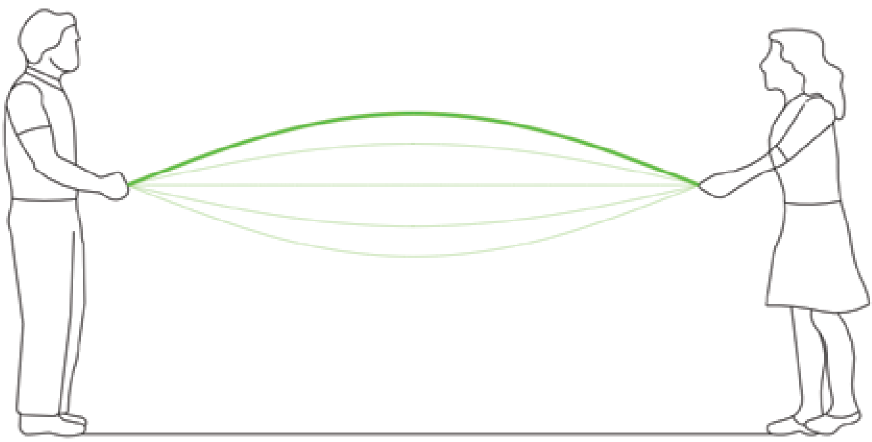


Figure 4: The fundamental.

Stop twirling and let the wave die. Move the switch back to the *constant-on* position and start again at twice the frequency. Once you have established the *second harmonic* wave as in Figure 5 continue for several cycles then move the switch to the forward *flashing-on* position.

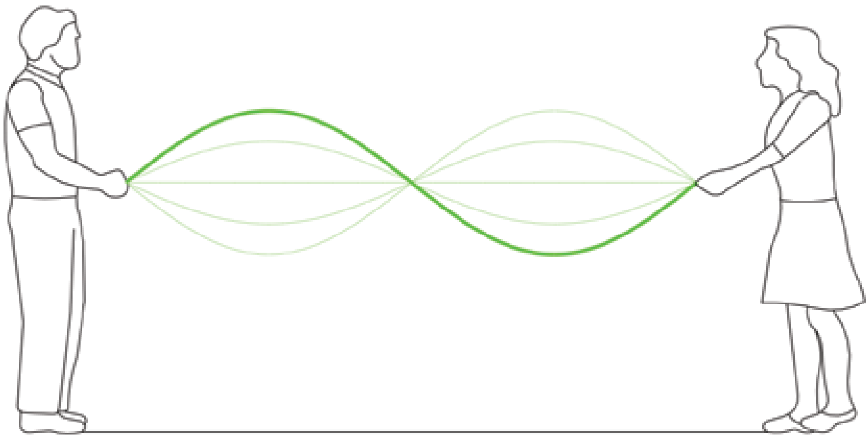


Figure 5: The second harmonic.

Now go for the third harmonic at three times the fundamental frequency, Figure 6.

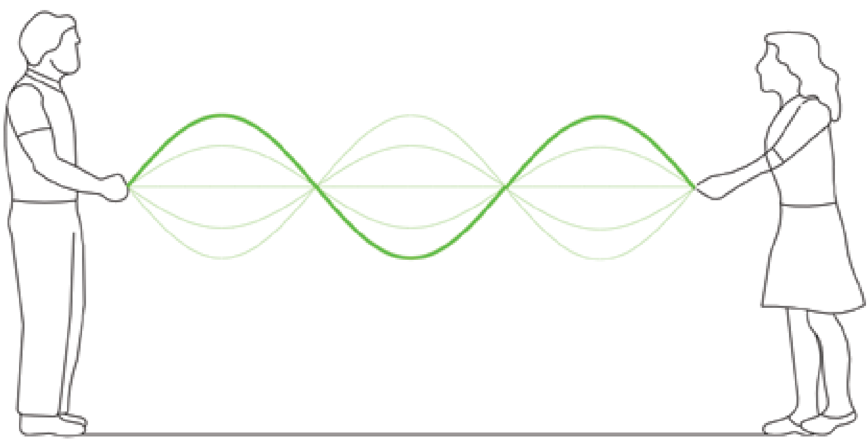


Figure 6: The third harmonic.

To safely achieve the fourth harmonic requires a longer and more massive wire.

STANDING WAVES
and
THE SUPERPOSITION OF WAVES
What's it all about!

(go to WWW.STROBOWAVE.COM to view animations)

Let's start by looking at some of the properties of a wave. We'll use a water wave as an example. The ***amplitude*** of a water wave is how high the wave is above where the water level would be if there were no waves at all. The simplest definition of the ***wavelength*** is it is the distance from the crest of one wave to the crest of the next wave; the crest to crest distance or the trough to trough distance (Figure 1). The ***wave speed*** is the speed that a crest is traveling horizontally.

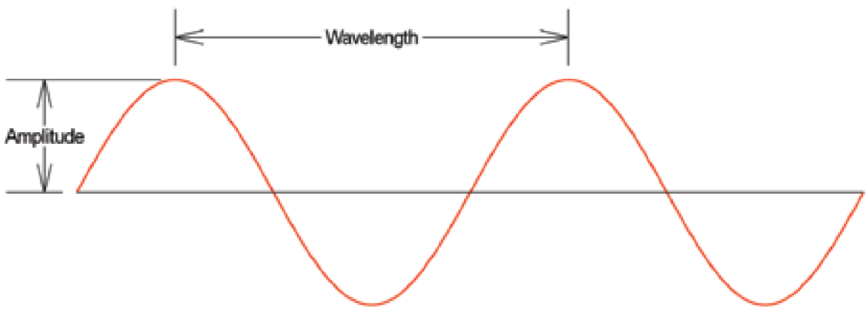


Figure 1: Wave parameters.

Waves are ***transverse***, like waves on a violin string or ***longitudinal*** like sound waves. A transverse wave is a wave where the medium in which the wave is traveling is jiggling up and down perpendicular to the direction the wave is traveling. A longitudinal wave is one for which the medium is jiggling back and forth in the same direction the wave is traveling. Animations of these and other wave types are can be seen at www.strobowave.com.

Throw a rock into a calm pond you will see a ring of ripples spreading outward from where the rock hit the water. The profile of the ripples would look something like Figure 2a. Now, imagine you are standing at the end of a long pier extending into a bay. The water is very calm and long graceful waves are heading toward shore (Figure 2b). If you throw a rock into the water here you will see a ring of ripples spreading outward from where the rock hit the water but now they will be riding on top of the incoming waves (Figure 2c). This is an example of the ***superposition*** of waves where one wave "stacks up" on top of another wave. Superposition is a property of all wave motion; water waves, waves on a piano or guitar string, sound waves, light waves and even seismic waves.

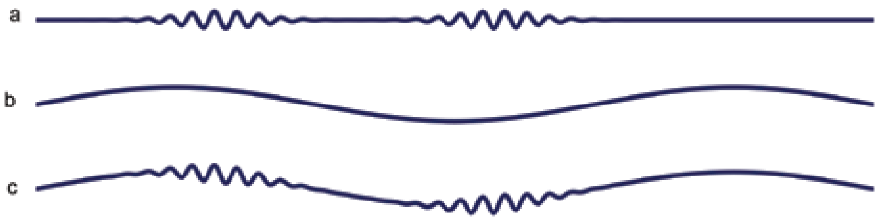


Figure 2: (a) Ripples. (b) Wave. (c) Ripples on wave

Ripples on top of a long water wave are easy to imagine but it gets really strange when the two waves have the same wavelength and amplitude.

When the crest of the blue wave in Figure 3 stacks on top of the crest of the red wave a "super" crest is produced while the trough of the blue wave pulls down the trough of the red wave to produce a "super" trough. This is called ***constructive interference***.

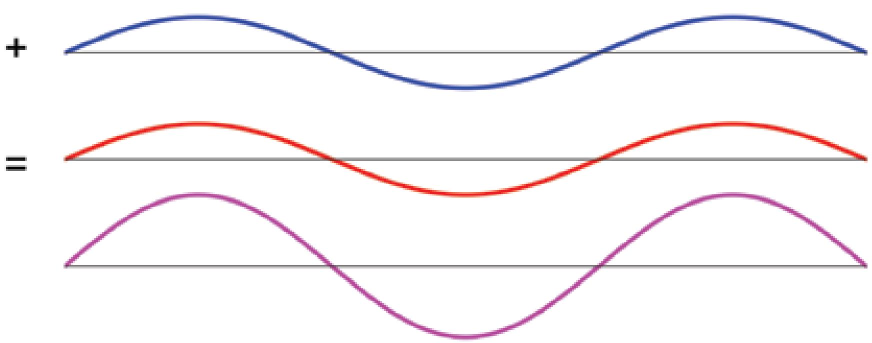


Figure 3: Constructive interference. Red wave + blue wave = magenta wave

The other extreme occurs when the crest of the blue wave in Figure 4 meets the trough of the red wave. The blue crest fills in the red trough and the blue trough is filled in by the red crest. This result in the two waves cancelling each other and producing ***destructive interference***. These are the two extremes and everything in between the extremes occurs.

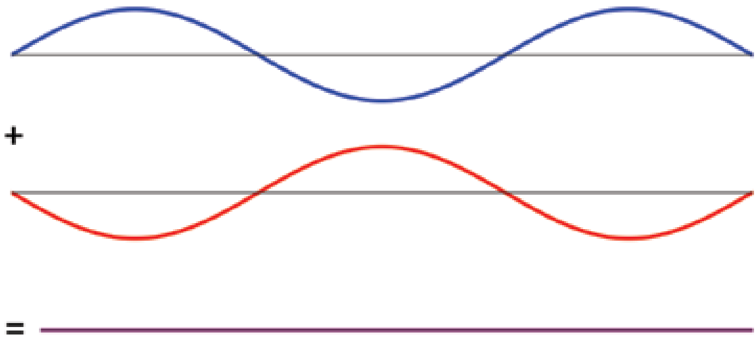


Figure 4: Total destructive interference. Red wave + blue wave = magenta wave

The waves you see at the seashore are examples of ***traveling waves***. The crest of a traveling wave moves horizontally at the wave speed. You can surf on a traveling wave.

A ***standing wave*** is actually two waves in one. A standing wave is the addition of a wave traveling from left to right and another traveling from right to left in the same medium with the same amplitude and wavelength. When you watch the animation you will notice that when the crests of the two opposite traveling waves are at the same place at the same time you get constructive interference producing super crests. Later, a crest and trough coincide and destructive interference occurs. The result of the superposition of the two traveling waves is that there are places along the medium where the two waves are continually canceling each other producing zero displacements. These zero displacement places are called ***nodes***. Between the nodes the medium is moving up and down. The peaks halfway between the nodes are called ***antinodes***. The distance from a node to an antinode is ¼ wavelength. If you look at the animation you will see that you can't surf a standing wave. Trying to surfing a standing wave gets you trapped and a nodal point.

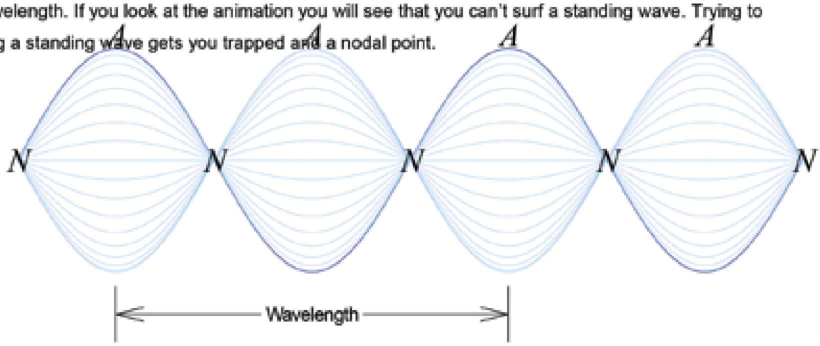


Figure 5: The nodes and antinodes in a standing wave.

On a standing wave, there is no horizontal motion of the crests or troughs as there is with a traveling wave. The superposition of the left and right traveling waves just produce crests that flatten and become troughs and troughs that rise and become crests; all up and down motion with no left to right or right to left motion.

Hand Vacuum Packing

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Abstract:
This is an apparatus that allows users to vacuum-pack their hand to a board and to feel the force of air pressure pushing down on their hand. The apparatus has been designed to be used as a classroom or outreach demonstration. It can also be used as an apparatus for self-guided hands-on exhibits.

Construction:
A small piece of ¾” thick plywood or 1x6 is cut with shallow grooves (~1/8”) in a grid pattern and then thoroughly smoothed (see figure 1). This plywood has a hole drilled in the center and is mounted to a ½” pipe flange and then to a 12” section of ½” pipe. The pipe is just the right size to push-fit/screw into the hose fitting that comes with the pump listed here (see figure 2). The plywood/pipe assembly is mounted to a table using a table clamp, and either a vacuum pump or a low-cost air blower is connected to the pipe.

The suction side of the pump is connected to the barbed fitting with the pressure hose. It is important to use a pump that does not have a vent on the suction side. Many pumps have a vent so that the pump will not overheat when a suction is drawn on device devoid of air. The pump listed in the materials has a small hole that can be sealed with a small piece of tape. You may have an older pump that has no vent hole at all.

A section of Diaper Genie bag is fitted over the wood and taped to the pipe to form an air-tight seal. The other end of the bag is sealed to the user’s wrist with a rubber band.

A momentary push-button switch is used so that the user can easily turn the pump on and off, and the fail-safe mode is that the pump will be off if the button is not pushed at all. To make the switch, which is very durable and can be used for many purposes, drill or punch a 30 mm hole just off-center on the 4x4 electrical box cover for the push button. Drill a 3/8” hole in the side of the 2x4x4 box. Cut the extension cord in half and strip the ends of all the wires. Insert the stripped ends into the box and use wire nuts to connect the ground and neutral wires. Connect the hot wires to the switch contact block. Use hot glue or epoxy to glue the wire ends in the box so they don’t pull out. Snap the contact block to the push button base and fasten the box lid onto the box. Alternatively, a much easier and cheaper switch method is to simply use a power strip with a switch, but this may not be as safe.

Fig. 1. Wood base.

Fig. 2. Assembled base.

Fig. 3. Assembled apparatus.

Fig. 4. Apparatus in use.

Use of Apparatus:

The students insert their hand into the bag so that the rubber bands slide over their wrists and seal onto their forearm. Then they simply push on the button to start the pump. A vacuum seal is established nearly instantly. Most students are surprised by the amount of force (pressure of course) exerted on their hand. You can then ask the students to try to lift their hand. It is difficult, if not impossible, for the hand to be lifted straight up.

This apparatus gives an excellent kinesthetic understanding of the pressure and force due to air-pressure. Most significant is that it shows how powerful air pressure can be.

If there is a concern about germs, a bottle of hand sanitizer is a great thing to keep nearby.

Materials:

Item	Source	Part #	Price
switch	Newark (Eaton)	10R1917	$4.87
NO contact block	Newark (Eaton)	10R1831	$7.69
ext. cord	home store	12' extension cord	$5.97
elect. box	home store	2x4x4 surface mount box	$6.54
plywood	scrap/home store	3/4" plywood (6"x9")	scrap
1/2" pipe flange	home store		$11.54
1/2" pipe	home store	12" threaded length	$5.78
Diaper Genie refill	Target		$6.89
air pump	Amazon	Swimline electric pump	$24.74
Table clamp, tape, rubber bands			exempt**
		TOTAL:	**$74.02**

**If a table lamp is not available, just zip tie the pipe to a C-clamp for a cheap home-made table clamp.

Viewing with an Endoscope

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Collaborators: Alex Spiro, Loyola University Maryland
Nancy Donaldson, Rockhurst University
Charles Gosselin, Rockhurst University

Background:

In 2012, Loyola University Maryland and Rockhurst University were awarded an NSF TUES collaborative grant to create three upper-division active learning physics modules on fiber optics and light delivery, nuclear physics and nuclear medicine, and pressure in the human body. Each of the modules relate physics principles to medicine and incorporate active learning and inquiry-based pedagogies. The target audiences are students interested in graduate studies/careers in health care and students interested in broadening their knowledge of physics to topics relevant to medicine and the human body. Instructor manuals are being written for each module to include goals, expectations about students' prior knowledge, materials list, experimental data, solutions, sites for computer simulations and instructional details. These instructor manuals can be easily edited to create student workbooks.

In one part of the module on fiber optics and light delivery, we introduce students to how we view organs and cavities inside our bodies with an endoscope based on fiber optics. Fiberscopes are advantageous where flexibility and a small diameter are required to image hard-to-reach or tightly packed areas. Typically the fiberscope consists of a light delivery system to illuminate the object-of-interest, and an imaging system consisting of a coherent fiber optic bundle. Instead of showing students the real endoscope, where it is hard to see all of the components, we have developed an apparatus that teaches students the basic principles of fiber optic endoscopes through the use of macroscopic acrylic rods. This material is also relevant for students interested in non-healthcare applications such as engine inspection and espionage.

Student and instructor guides:

The full set of student guides to the Fiber Optics Module (Level 1)is located at

https://www.mededportal.org/icollaborative/resource/876

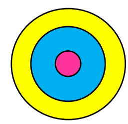
These student guides have been updated since being deposited. For the latest versions, please email us to obtain Instructors' Guides, which can be easily transformed into student guides.

Acknowledgment: We wish to acknowlege suppport from NSF TUES Collaborative Grant Awards DUE-1140390 and DUE-1140406.

Materials

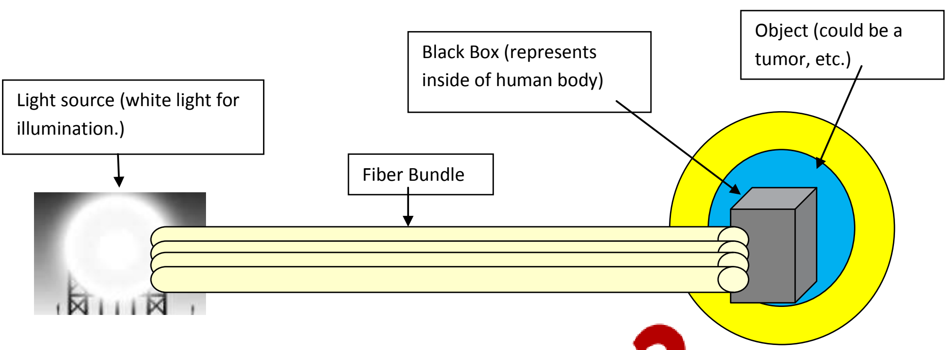
- ✓ LED white light bulb (the brightest possible), ex. Sylvania ULTRA LED PAR30 bulb, 880 lumens, purchased from Lowe's.
- ✓ Socket and power cord for bulb, mounted.
- ✓ Aluminum foil or black cloth.
- ✓ Bundle of ~25 ¼" polished acrylic rods, ~18" in length, for illumination.
- ✓ Bundle of ~100 1/8" polished, round acrylic rods, ~18" in length, for viewing.
- ✓ Bundle of > 300 1/16" polished, round acrylic rods, ~18" in length, for viewing.
- ✓ Bundle of ~100 polished, 1/8" square acrylic rods, ~18" in length, for viewing.
- ✓ Isolated polished rod (any diameter, ¼" is good) to look at a single pixel.
- ✓ 60 mm Ø2" converging lens (Thorlabs LA1401) with lens mount (LMR2), 1.5" post (TR1.5), 1.5" postholder (PH1.5), base (BA2).
- ✓ Blocks to elevate illumination bundle. For example, 2x4 wood with groove. Books can also work.
- ✓ Blocks to elevate viewing bundle. For example, 2x4 wood with groove. Books can also work.
- ✓ Colorful yellow-cyan-magenta object, which represents an organ or a tumor, mounted vertically. See last page of this document.

Introduction



Suppose this object is an organ inside the human body, and you want to look at it carefully.

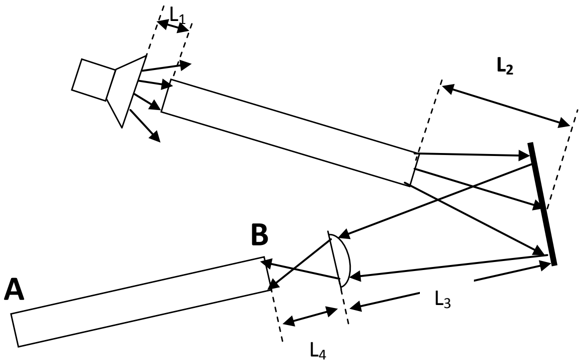
We want to illuminate the object with a lot of light, so we'll use a "fiber" bundle (set of acrylic rods) to transfer light and illuminate the whole object. Imagine that our "fiber" bundle enters a large black box (representing the human body) to illuminate an object (organ to be viewed). Our goal is to get the image of the object back out of the box so that it can be viewed outside of the box.



Question: How do we create an image of the object (organ) and then get the image back out of the body to our eye?

Experimental setup

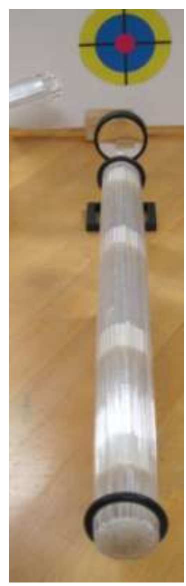
The illuminating rods are ¼” in diameter and the viewing rods receiving the light are 1/8” in diameter with a round cross section. Position the rod bundles so that they are at the correct height. The illumination bundle needs to collect as much light as possible from the LED bulb. Use foil or cloth to block light from the LED that does not enter the illumination bundle.



Typical values for illumination are:
L_1 = 0 to 20 mm.
L_2 = 120 mm

Typical values for viewing are $L_3 = d_o$ = ~240 mm, $L_4 = d_i$ =~62 mm, where f = 60 mm (back focal length = 49.2 mm for Thorlabs lens).

Other lenses are possible. For example, for a 10 cm lens, d_o = 44 cm, d_i = 12.9 cm (approximate)



Teaching Materials

We have extensive teaching materials that go along with this setup. A few questions are shown here, but the full instructors' guide with answers may be obtained at the location described under Background.

- What would be the advantage of using a white light source for illumination as opposed to a laser?
- A white light source would have a large divergence, unlike a laser beam. Using a white light source, what do you think are some ways to increase the *brightness* of the object?
- When the light from the fiber optic bundle illuminates the object, what kind of reflection do we get off of the object?
- Why is a fiber bundle used to illuminate the object instead of a single, large diameter fiber?
- When the light from the object passes through the converging lens, where does the image form – at the focal point of the lens or somewhere else?
- You adjusted the location of your lens until the image was the correct size to fit the diameter of the viewing bundle. As you moved the lens back and forth, how did do and di vary with each other? If the image was too big, what did you have to do to reduce the magnification?
- Once the image forms at position B, how does it get from B to position A where you see it?
- Do you think the image at B is right side up or inverted? Why?
- Do you think the image at A is right side up or inverted? Why?
- Test your answer on the apparatus by placing your finger on one side of the object and viewing the image as you move your finger back and forth toward the center of the object. What did you see?

- Carefully measure the diameter of the object and the diameter of your viewing bundle. Be careful to measure the part of the object you are viewing in your bundle. What is the magnification m? *You will use these measurements in your homework problem solving.*

- Why do the rods of the viewing bundle need to be arranged in a coherent manner?

- Does the illuminating bundle need to be coherent?

- Why is the viewing bundle called an “image conduit?”

- (Optional) Instead of viewing the image with your eyes, use another lens to focus the image onto a screen. This is what a camera would do. Record the settings of this second lens.

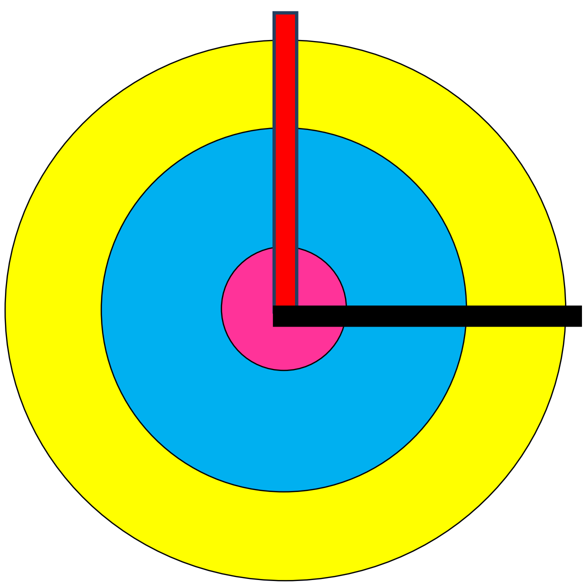
- Why are smaller diameter rods used on the viewing side of the demo? Do we also need to use this size rod on the illuminating side of the demo? Why or why not? What cost factors do you think this has in development of a real fiberscope?

- We also want to increase the resolution of the image we receive on the outside of our box. You have been working with 1/8” viewing rods. What do you think would be a good way to increase the resolution of the image? What does resolution mean?

- Now try the bundle of 1/8” square acrylic rods. Compare the image from the 1/8” round rods to the image from the 1/8” square rods. Which image is better and why?

- In real fiber bundles, fibers with round cross sections are used. What can be done to optimize the image?

Sample of Object



Polishing Instructions for Acrylic Rod and Plastic Optical Fiber

For all of the fiber optic activities, the ends of the acrylic rods must be polished. The students should not touch the ends with their fingers, but if that happens, you can wipe the end with a silver jewelry polishing cloth (see below). We have tested our polishing procedure on the following fibers or rods:

- ¼” acrylic rod
- 1/8” acrylic rod
- 1/16” acrylic rod
- 2 mm plastic optical fiber

There is no one method for polishing. What you do will depend on the type of equipment available to you. Here are several recommendations:

<u>1. Plastic optical fiber</u>
Cut the fiber with a scissor. Try to get the cut end as straight as possible to reduce polishing time. If the end is crooked, you can quickly take down the point with a coarse grit sandpaper.

Manual method for polishing: Start with coarse grit (400 or 600). Lay the grit flat on the table. Move the fiber in circular or figure 8 motions, about 15 sec for each grit. Gradually work your way up to 1200 or 1500 grit. Finish with a Hagerty silver jewelry polishing cloth (see item #2).

(We have also heard of a hot melt knife but we have never tried it.)

<u>2. Acrylic rod (1/4” or 1/8” or 1/16” diameter)</u>
Saw cut and flame polish.
Mr. Plastics Inc., 510-895-0774
Volume discounts are available.
The saw cut and flame polish technique produces a finish in which the edges are a little rounded. The finish is acceptable for the viewing bundles.

<u>3. Acrylic rod (1/4” or 1/8” diameter) – individual rods</u>
Cut with a band saw.
Mill one end.
Mill the other end.

Polish each end manually: Lay the grit flat on the table. Move the end of the rod in circular or figure 8 motions. Start with coarse grit (ex. 600) and get progressively finer (ex. 1200 or 1500 grit). Finish with a Hagerty silver jewelry polishing cloth.

Alternatively, use a buffing wheel with rouge. This procedure is quick but it can produce rounded edges.

Best quality: Use a Leco grinder/polisher. Use grits 800, 1200, polishing cloth with alumina oxide in water.

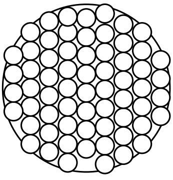
Useful to have: Hagerty silver jewelry polishing cloth (purchased from Amazon). This cloth has a white, inner cloth for polishing and a gray, outer cloth for buffing. Look at the reflection from each end of the rod to evaluate the quality of the polishing.

<u>4. Acrylic rod (1/4” or 1/8” diameter) – large quantities</u>

Step 1. Cut the required number of six foot acrylic rods into four pieces, each approximately 18 inches long, with a band saw or hack saw.

Step 2. Cut a piece of 1.5 inch diameter heat shrink tubing about 5 to 6 inches long.

Step 3. Insert 30 lengths of 1/4 inch diameter acrylic rod or 99 lengths of 1/8 inch diameter acrylic rod into the 1.5 inch diameter heat shrink tubing. Adjust the rods so that they are straight and not twisted and the heat shrink is approximately centered along the rods. Form the bundle of rods in a circular pattern and wrap a piece of duct tape (about 6 inches long) around each end. The outer edge of the tape should be about 3 inches in from each end. The tape is intended to maintain the circular shape of the bundle of rods.



Step 4. Cut about 1/4 inch off each end of the bundle of rods with a band saw. The purpose of these cuts is to provide flat ends on the rod bundle. **Important note**: The acrylic rod must be cooled when cut or the heat generated will melt the acrylic. The cooling can be accomplished by submerging the end being cut into a water bath repeatedly while cutting. Cut for about one second and then remove from saw blade and dip into water—cut for another second and dip again. Do not try to cut at a fast rate. After a few practice cuts, you can determine what works. The white debris is melted acrylic.

Step 5. Sand each end of the rod bundles on a disk sander so as to maintain the flatness of each end. The sanding procedure is carried out with a sequence of smaller and smaller grit sandpaper, i.e. 100, 200, 300, 400, and 600. Continue sanding at each grit level until all of the scratches from the previous grit level have been removed. Between each grit level, check the uniformity of the rod ends by pointing the rod bundle at a bright light source to judge the transparency and uniformity of the polished ends.

Step 6. After it appears that you can see the inside of the rods when the rod bundle is pointed at a bright light (do not use a laser), polish the rod ends with a soft buffing wheel. Use very light pressure during buffing. A tiny amount of rouge compound applied to the buffing wheel can sometimes improve the polish. However, too much rouge can cause discoloration and leave rouge deposits on the sides of the rod ends.

Step 7. When polished properly, each of the rod end surfaces should have a high level of specular reflection and be very transparent when pointed at a bright light source (not a laser).

How to Build the Viewing Bundle

Several types of bundles may be used with the viewing activity (Section 6). This section describes the procedure for making the bundles. It is exceedingly important that the rods in the viewing bundles are **coherent**, i.e. the rods need to be aligned in exactly the same way at both ends. The set of steps to achieve a coherent bundle depends on the diameter of the rods.

<u>1. Bundle of ~25 ¼" polished acrylic rods, ~18" in length, for illumination.</u>
Do it yourself: Refer to the document with the filename "Instructions_Polishing." The best way to obtain a set of acrylic rods with the same length is to follow the procedure described in the document in which the rods are bundled tightly with heat shrink tubing and tape. Then mill both ends of the bundle so that all of the rods have the same length. Follow the procedure to polish.

Use a company: Many plastics companies will be able to cut and flame polish the rods. We used Mr. Plastics (510-895-0774). It is possible that the rods will have slightly different lengths. This is acceptable for illumination. Bundle the rods with heat shrink tubing, tape, or glue.

<u>2. Bundle of ~100 1/8" polished, acrylic rods with circular cross section, ~18" in length, for viewing</u>
Do it yourself: Refer to the document with the filename "Instructions_Polishing." The best way to obtain a set of acrylic rods with the same length is to follow the procedure described in the document in which the rods are bundled tightly with heat shrink tubing and tape. During the process of bundling, make sure each rod is parallel and aligned so that the relative positions of the rods are the same for both ends of the bundle. Then mill both ends of the bundle to achieve the same length for all rods. Follow the procedure to polish.

The "jellyroll" method: We used Mr. Plastics (510-895-0774) to saw cut and flame polish the rods. The rods vary slightly in length, but are still usable for the viewing bundles. After receiving the rods from the company, spread the rods out parallel to each other on a table. Use a straight edge to make one side of the rods even. Run a long piece of masking tape perpendicular to the rods near one end. Run another piece of tape in the middle, and another at the other end. Then roll the rods up tightly like a jelly roll. When finished, wrap tape around the bundle to hold it together.

<u>3. Bundle of > 300 1/16" polished, round acrylic rods, ~18" in length, for viewing.</u>
We used Mr. Plastics (510-895-0774) to saw cut and flame polish the rods. The rods vary quite a bit in length, but are still usable for the viewing bundles. Follow the jelly roll method described above.

<u>4. Bundle of ~100 polished, 1/8" acrylic rods with square cross section, ~18" in length, for viewing.</u>
We used Mr. Plastics (510-895-0774) to saw cut and flame polish the rods. After receiving the rods from the company, stack the rods on a table to create a bundle with a square cross section. Wrap tape on the outside to hold the outer rods in place. The inner rods can slide; this is OK but you will have to even out the rods before each use.

Negative Ion Gun

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Abstract:

An inexpensive negative ion source is contained in a metal box. It shoots the ions out one end and can be directed to an insulated soda-pop can that charges up. A grounded soda pop can is near by. A conductive Ping Pong ball is hung between them, and transfers charge by bouncing back and forth. Students can experiment with distances to affect the speed of bounce of the Ping Pong ball.

Construction of apparatus:

The low-cost negative power supply is mounted in a grounded square double gang metal electrical box with a plastic cover. The cover supports the high-voltage output wire which emits negative ions. The box also has a momentary power switch and a monitor lamp. A three-prong power cord is attached to the box to assure the box is grounded. The box is placed on a metal sheet which is the ground plane. In front of the ion source is a soda pop can that is insulated from the ground plane by a plastic base. When the switch is pressed, negative ions charge up the insulated can. A conductive Ping Pong ball is suspended near the charged can, aquires a negative charge, and is repelled. If the grounded soda pop can is near enough, the ball will bounce back and forth, transfering the charge to the ground.

Use of apparatus:

Placed on a table in a hallway, students can press the switch and watch the Ping Pong ball respond. Furthermore, they can move the cans around to see how the distance from the ion source and between the cans will effect the bouncing frequency. When the switch is released, the bounce continues as the charge decreases. A larger can will provide a greater charge storage, allowing the students to get a feel for capacitance.

Fig. 1.

Fig. 2.

Egyptian Rope Trick

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Abstract:

Using 17 m length ropes, one white, one red, one blue, and two cardboard discs, and a cloth meter length ruler, you have the basic parts needed to teach Trig functions. Mark off the ropes at each meter of length. Draw angles of 37, 53, 45, 45, 30, 60 and 90 on each disc.

Use of apparatus:

Use the red rope to set up the sine components and blue rope for the cosine components. The white rope will go from the start of the sine component to the end of the cosine component. Determine the area behind each of the ropes. The area of the red and blue will equal the area of the white. Measure the angles to find the values.

Pythagoras was educated in Egypt. The high priests were called "rope benders." Using the area behind the two components they knew they had created a right triangle with a valued line of site. His work expanded this to the math we use today.

By using the tactic approach, it is much easier for the students to understand the components of a right triangle. This can be used in multiple vectors once the students see how the red and blue ropes produce the components of a vector.

Colorimeter

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Abstract:

A colorimeter is a device used to measure the absorbance of specific wavelengths of light by a solution. My school couldn't afford a class set of student colorimeters, so I designed and built some from components. Other than the low cost, this device is unique because it calculates standard error, uses a "teachable" two-point calibration, is controlled by a single button, has an open source operating system, and displays results on a built-in screen.

Construction:

The colorimeter was prototyped and programmed using Arduino and is built around an ATmega328 microprocessor. The optical system consists of a three-color LED (wavelengths of 630/525/465 nm) and a CdS photoresistor. A 32-character monochrome LCD display guides the student through calibration and displays measurements. Power is supplied by a 9 V battery. The controls consist of an on/off toggle and a push-button to control the calibration/measurement cycle.

In the current iteration, the colorimeter is built on stripboard and housed in a cardboard case. A breadboard prototype will also be on display. The operating system for the colorimeter was written and uploaded to the microprocessor using the Arduino IDE. Schematics, a parts list, construction details, and source code are available from the author.

Use of apparatus:

The colorimeter uses standard (10 mm) cuvettes. First, the user will need to calibrate using blank (0% transmission) and clear (100% transmission) cuvettes, following the on-screen guide. Next, the user places the sample cuvette into the colorimeter.

For the sample, 10 measurements are made for each of the three colors. Average values of the transmission and absorbance are calculated, along with the standard error for absorbance, and displayed on the screen sequentially by color. After displaying the results, the device must be re-calibrated.

Two education-oriented aspects of this device are worth mentioning. First, the calibration process is made clear. The potential difference across the photoresistor measured in the presence of the blank cuvette is assigned a transmission of 0%, the potential difference with the clear cuvette is a 100% transmission, and thus the sample measurements are interpolated accordingly. Second, the device reports a standard error from 10 measurements. This gives the student a suitable number to use for uncertainty propagation calculations or, in experiments where replications are used to estimate the random error, saves a great deal of time.

Colorimeter

Danny Doucette, International School of Latvia

Part List

Item	cost per unit (EUR)
ATmega328	2.03
28-pin IC socket	0.31
16MHz crystal oscillator	0.33
1kΩ resistor	0.06
10kΩ resistor (2)	0.05
560Ω resistor	0.05
5V regulator	0.37
10nF capacitor	0.10
22uF capacitor	0.13
22pF capacitor (2)	0.08
CdS photoresistor	1.75
RGB LED	0.94
pushbutton switch	1.54
16x2 LCD display	7.84
9V battery connector	0.37
header strip	0.20
switch	1.55
10kΩ potentiometer	0.40
stripboard	3.59
Total	21.82 (=29.68 USD)

also: wire, solder, case, heat-shrink tubing, Arduino for programming

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