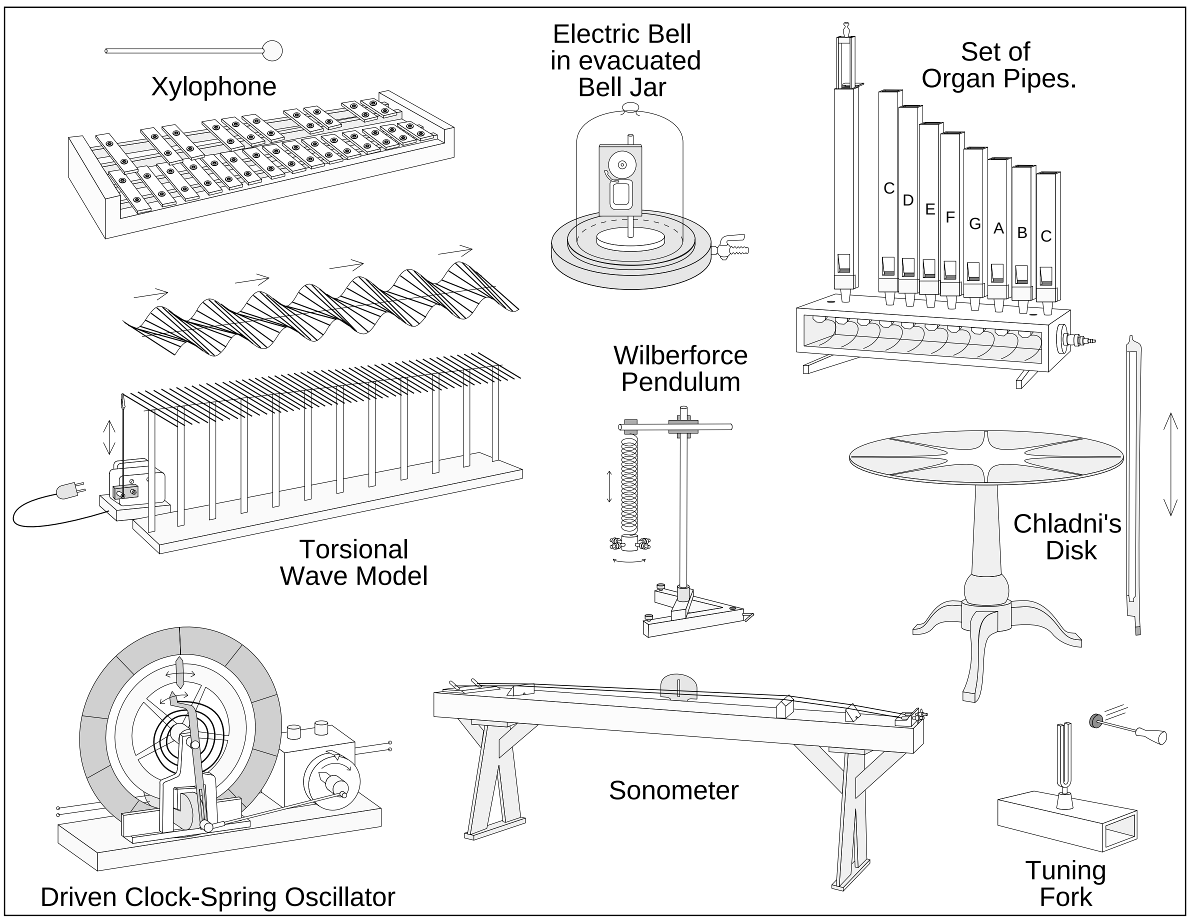
Notebook 'B': Physics Waves Lecture Demonstrations



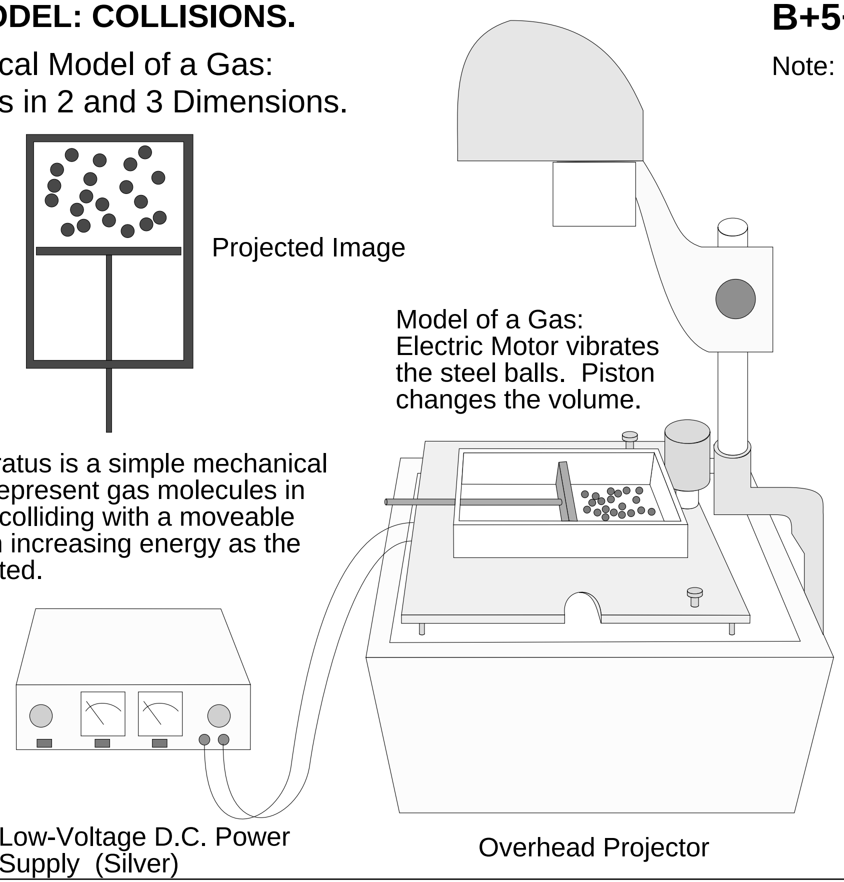
GAS MODEL: COLLISIONS.

B+5+0

Mechanical Model of a Gas:
Collisions in 2 and 3 Dimensions.

Note: Same set-up as A+35+30

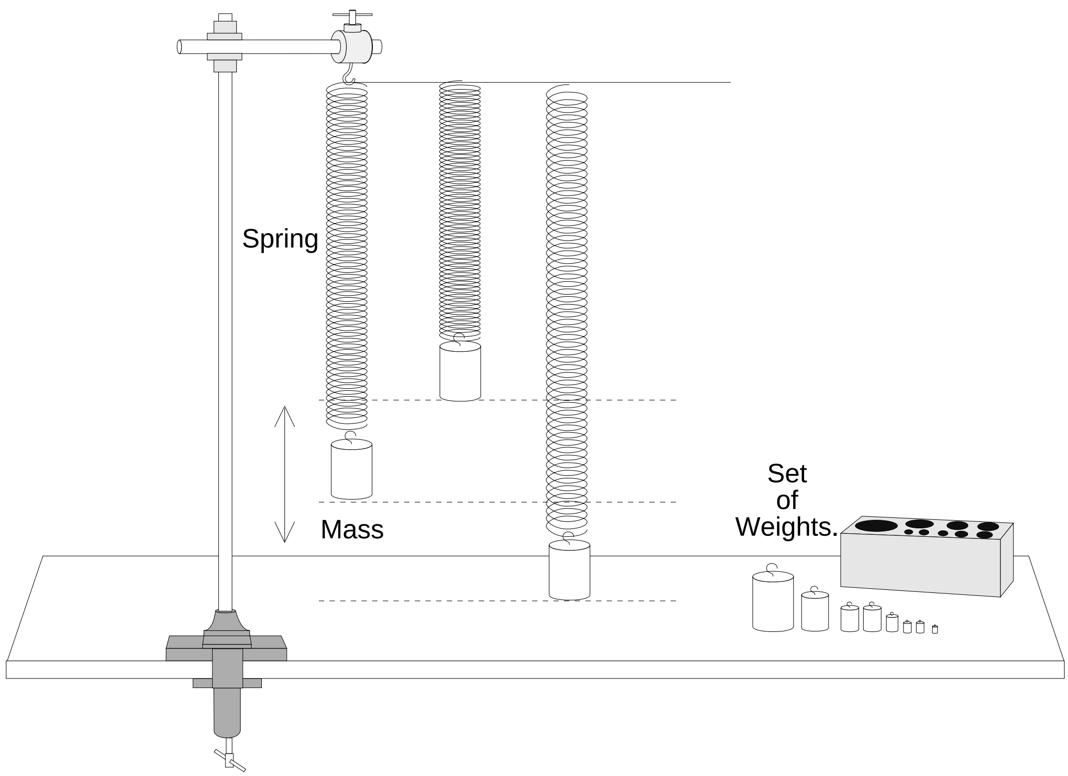
The Apparatus is a simple mechanical model to represent gas molecules in a cylinder colliding with a moveable piston with increasing energy as the gas is heated.



SIMPLE HARMONIC MOTION.

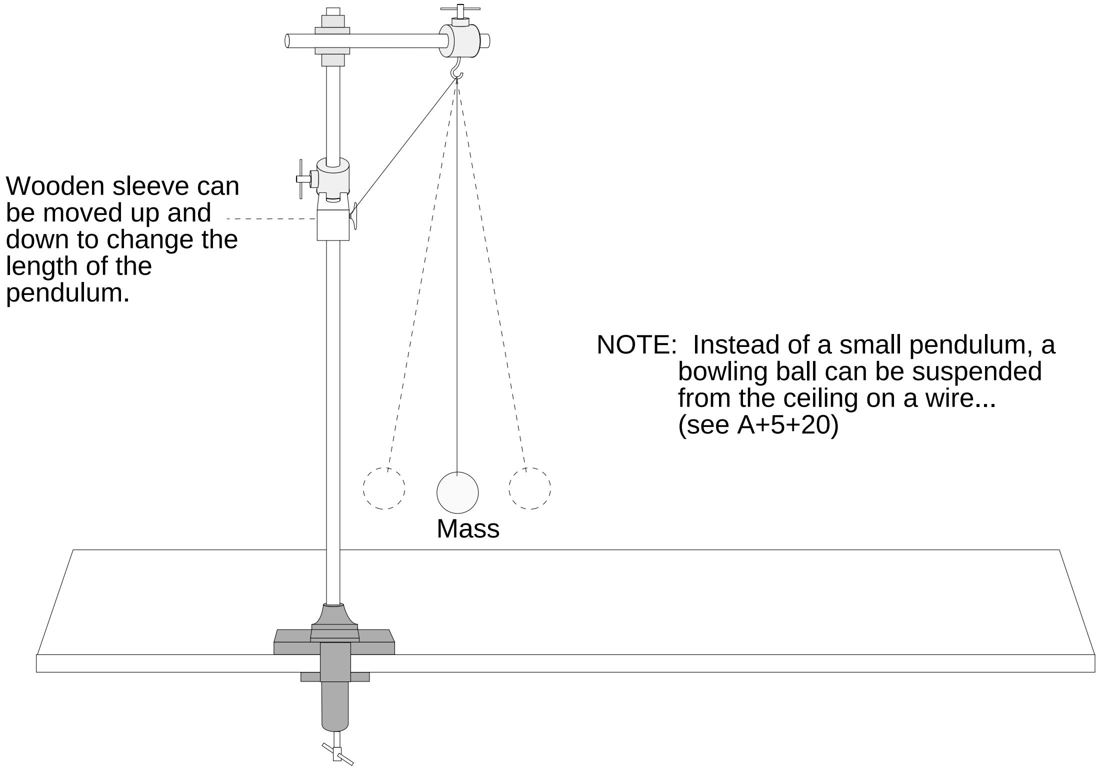
B+10+0

Oscillations: Mass on a Spring.



SIMPLE HARMONIC MOTION. **B+10+1**

Oscillations: Simple Pendulum,-Mass on a String.



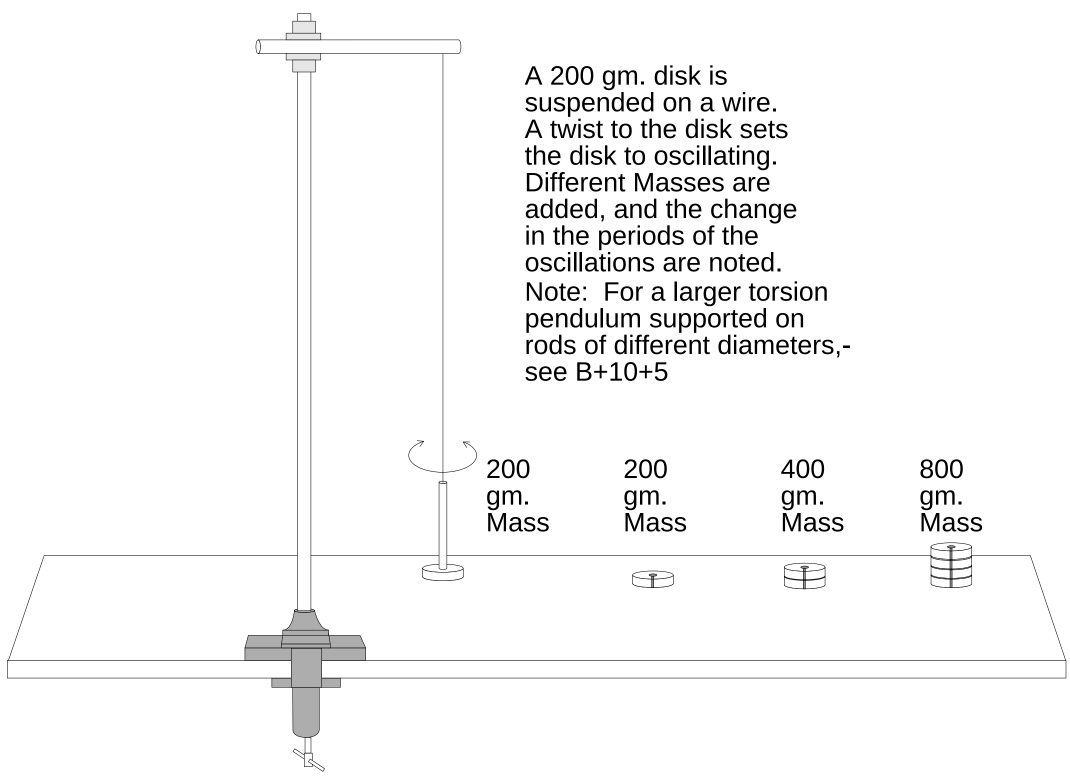
NOTE: Instead of a small pendulum, a bowling ball can be suspended from the ceiling on a wire... (see A+5+20)

SIMPLE HARMONIC MOTION. **B+10+2**

Oscillations: Torsionsal Pendulum,-Mass on a Wire.

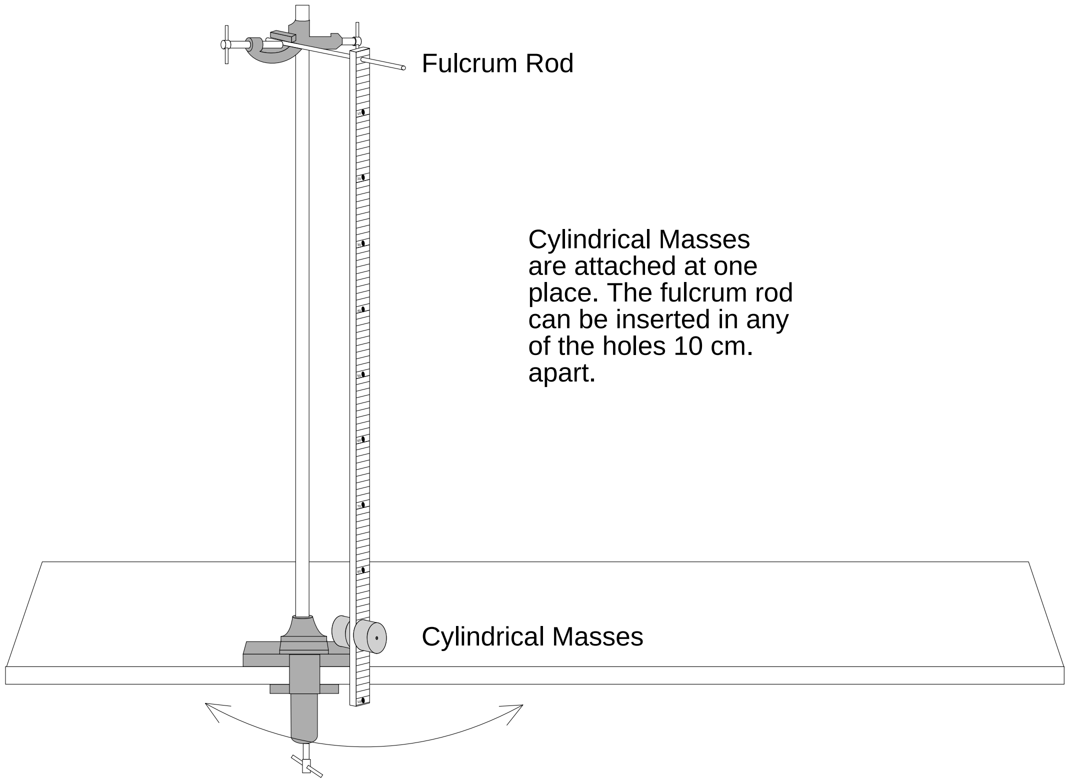
A 200 gm. disk is suspended on a wire. A twist to the disk sets the disk to oscillating. Different Masses are added, and the change in the periods of the oscillations are noted.

Note: For a larger torsion pendulum supported on rods of different diameters,- see B+10+5



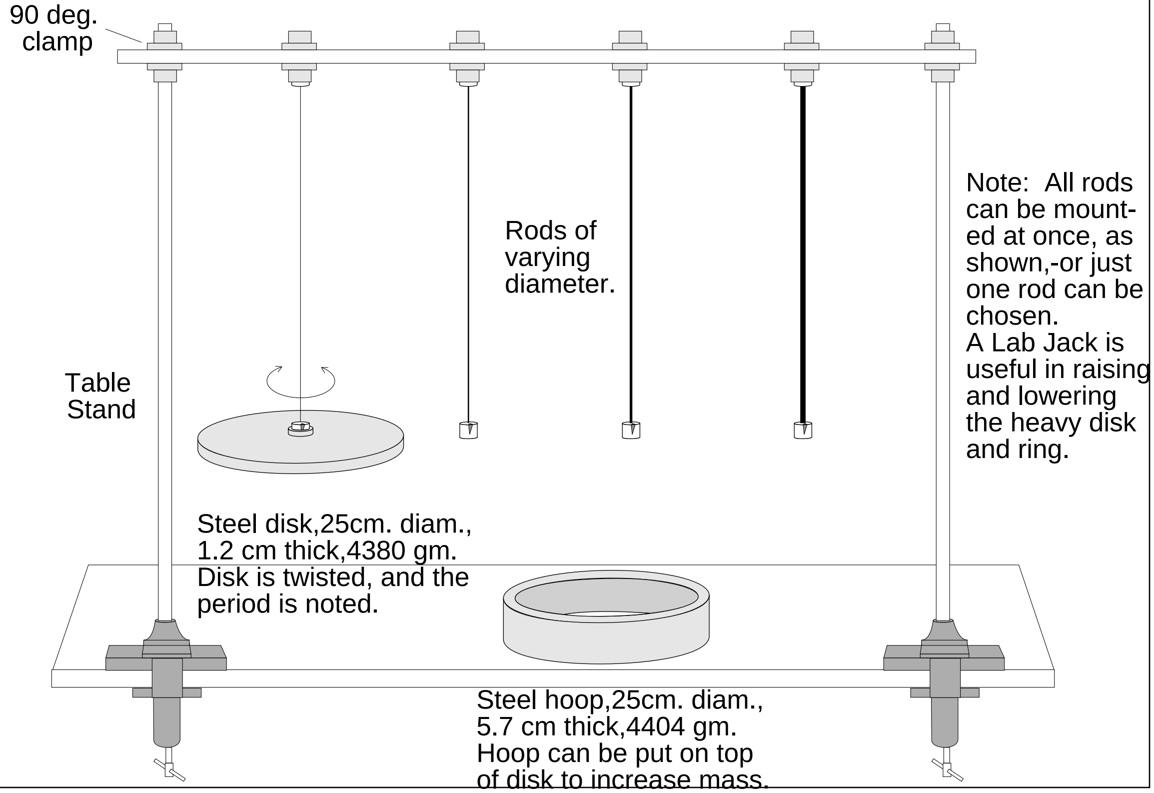
SIMPLE HARMONIC MOTION. **B+10+3**

Oscillations: Compound Pendulum,-Mass on a Stick.



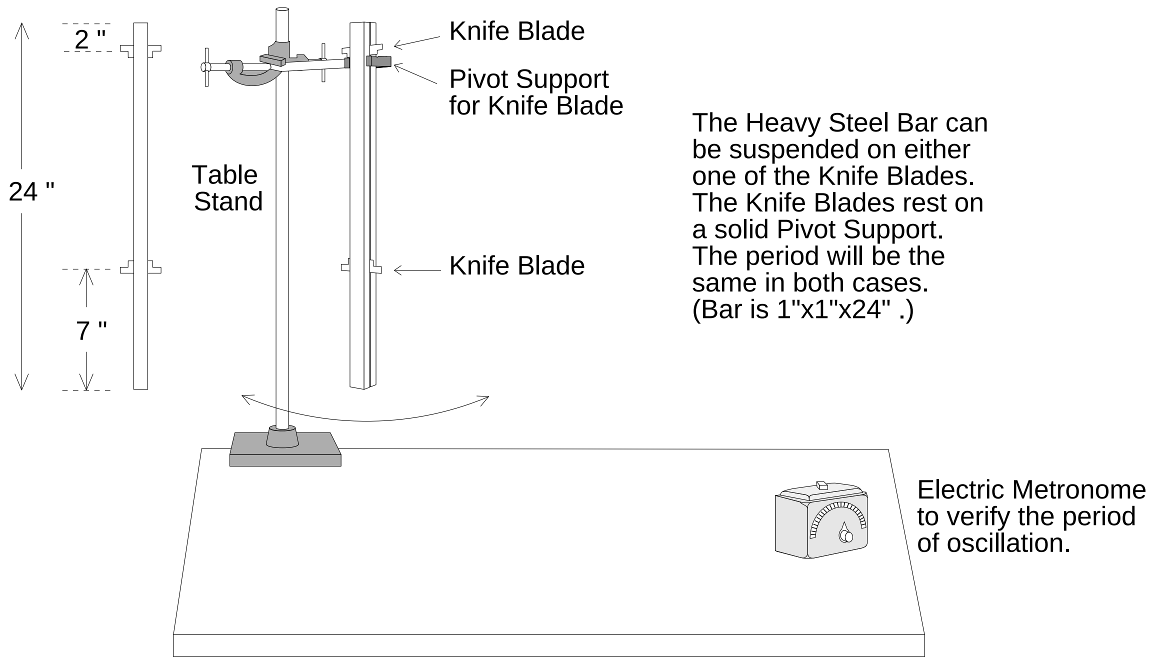
SIMPLE HARMONIC MOTION. **B+10+5**

Oscillations: Large Torsion Pendulum on a Rod.



SIMPLE HARMONIC MOTION. B+10+10

Oscillations: The Physical Pendulum.



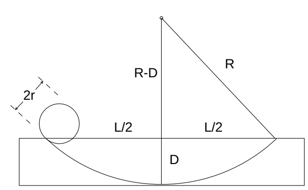
The Heavy Steel Bar can be suspended on either one of the Knife Blades. The Knife Blades rest on a solid Pivot Support. The period will be the same in both cases. (Bar is 1"x1"x24" .)

SIMPLE HARMONIC MOTION. B+10+15

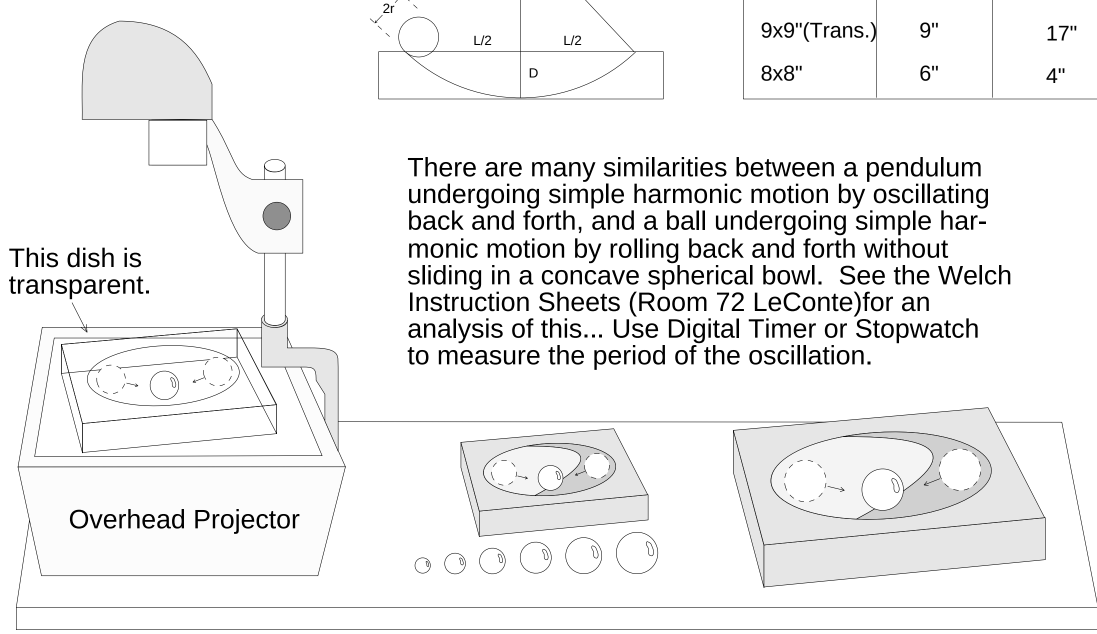
Oscillations: Ball rolling in a Spherical Dish.

There are 3 models. Two are gray plastic, and one is transparent.

Model Size	Diameter of Dish L	Radius of Curvature R
15x15"	13"	32"
9x9"(Trans.)	9"	17"
8x8"	6"	4"



There are many similarities between a pendulum undergoing simple harmonic motion by oscillating back and forth, and a ball undergoing simple harmonic motion by rolling back and forth without sliding in a concave spherical bowl. See the Welch Instruction Sheets (Room 72 LeConte)for an analysis of this... Use Digital Timer or Stopwatch to measure the period of the oscillation.

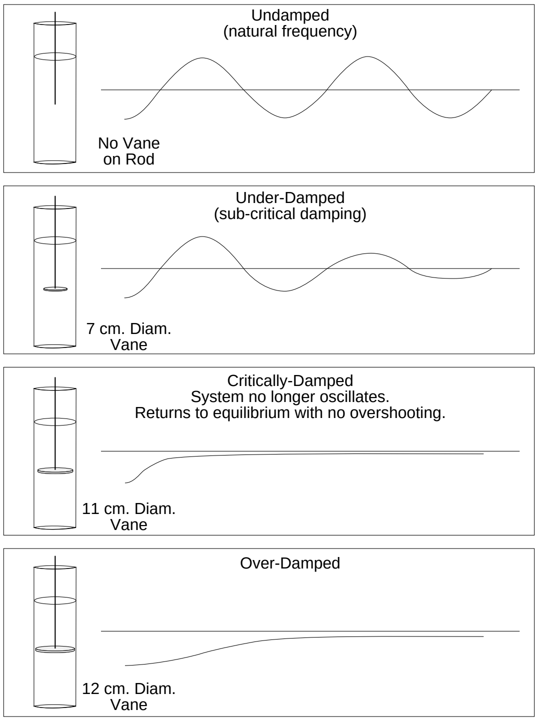


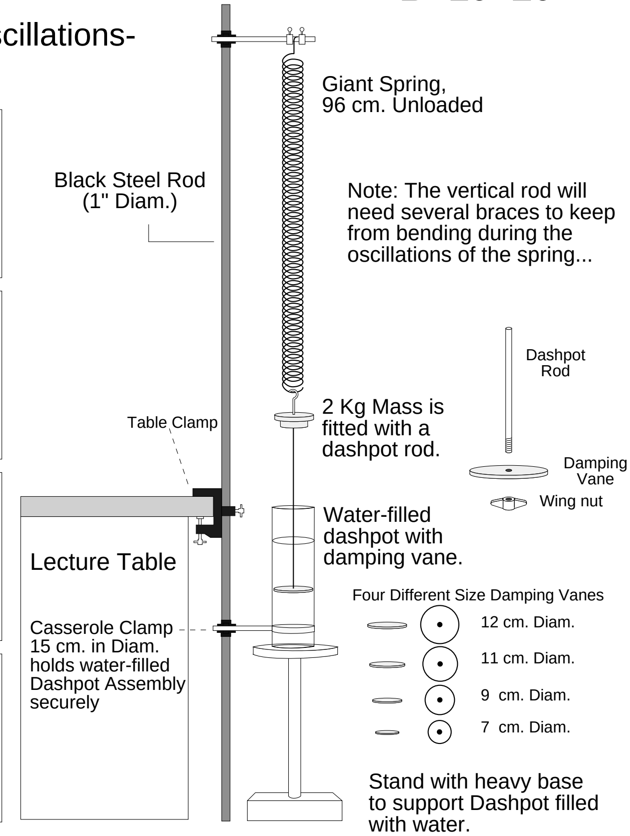
Steel Ball Diameters: 3/8,1/2,5/8,3/4,7/8,1"

SIMPLE HARMONIC MOTION.

B+10+20

Oscillations: Damped Harmonic Oscillations-Spring and Dashpot Assembly



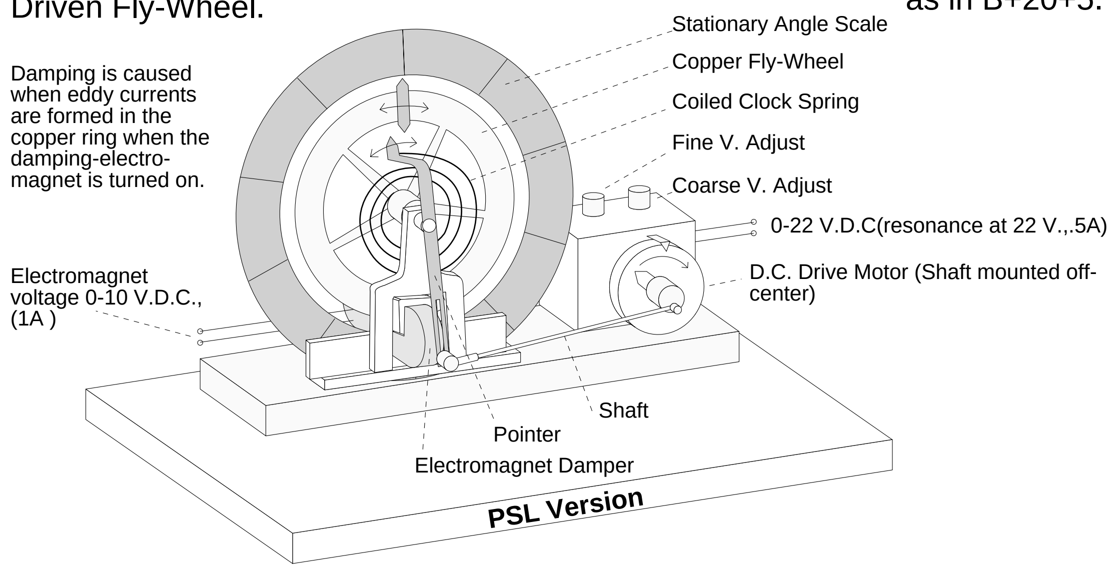


SIMPLE HARMONIC MOTION.

B+10+25

Resonance and Damped Harmonic Motion of a Driven Fly-Wheel.

Same apparatus as in B+20+5.



Drive Motor pushes Shaft, driving the Pointer back and forth,-pushing the Clock Spring which connects to the Copper Fly-Wheel. The amplitude of the swing of the fly-wheel depends on the frequency of the motor.

Note: There are two versions of this demo. The one at PSL is half the size of the one in Le Conte, but works better. The one in PSL can use portable D.C. Power supplies; Coarse and Fine Voltage controls are used to find resonance (1 sec. period).

The Le Conte Version is being modified to use A.C. power for the motor, and D.C. power for the damping electromagnet. For D.C., the Ballast Resistance on the Control Panel must be adjusted . (2 sec. period).

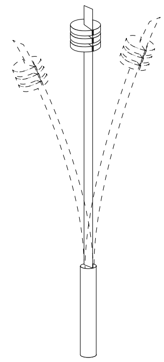
SIMPLE HARMONIC MOTION.

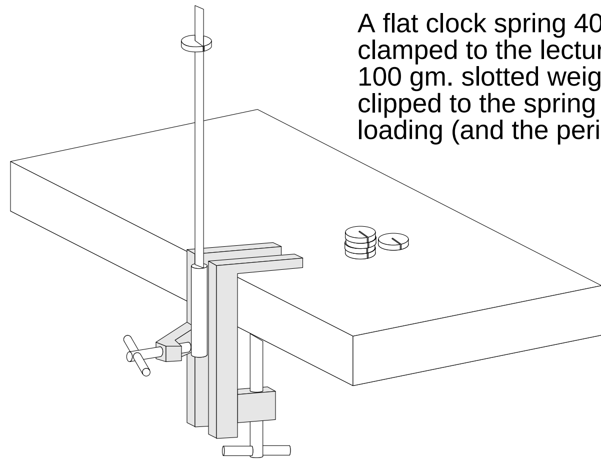
B+10+30

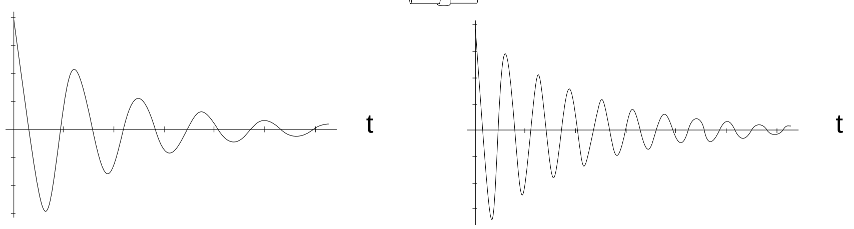
Damped Oscillations: Spring Steel Band with weights.

Same apparatus as in B+45+0.

A flat clock spring 40 cm. long is clamped to the lecture table. 100 gm. slotted weights can be clipped to the spring to vary the loading (and the period).





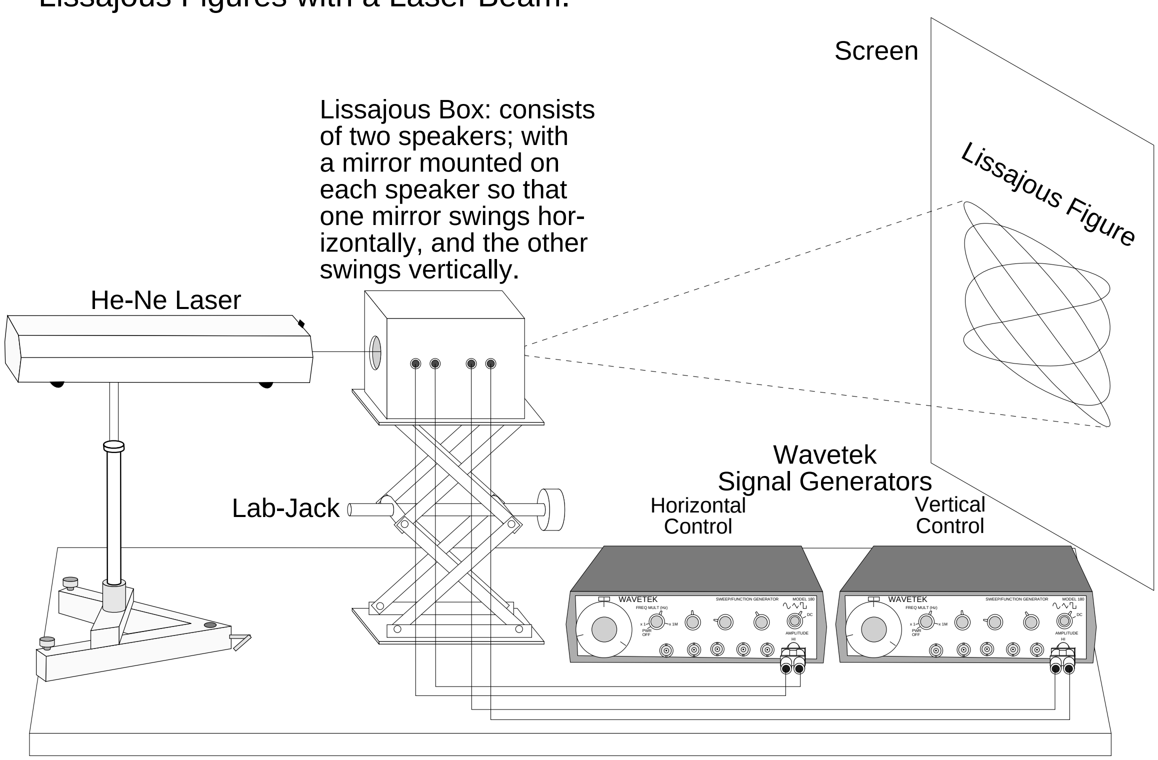


More Mass clipped to Spring. Less Mass clipped to Spring.

SIMPLE HARMONIC MOTION.

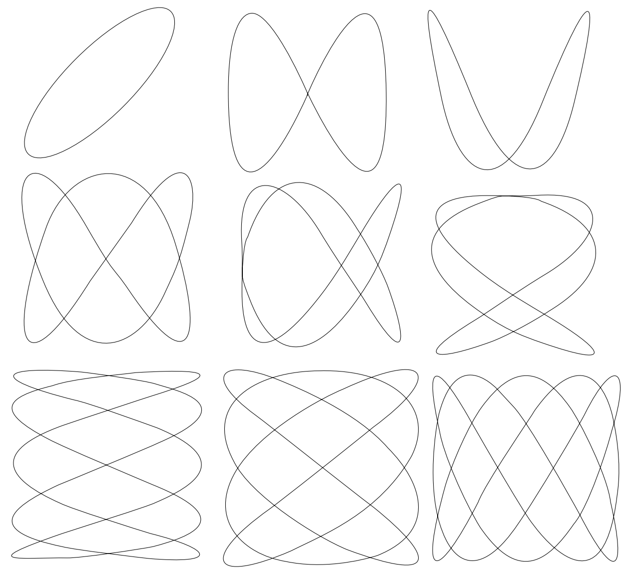
B+10+35

Lissajous Figures with a Laser Beam.



SIMPLE HARMONIC MOTION. **B+10+40**

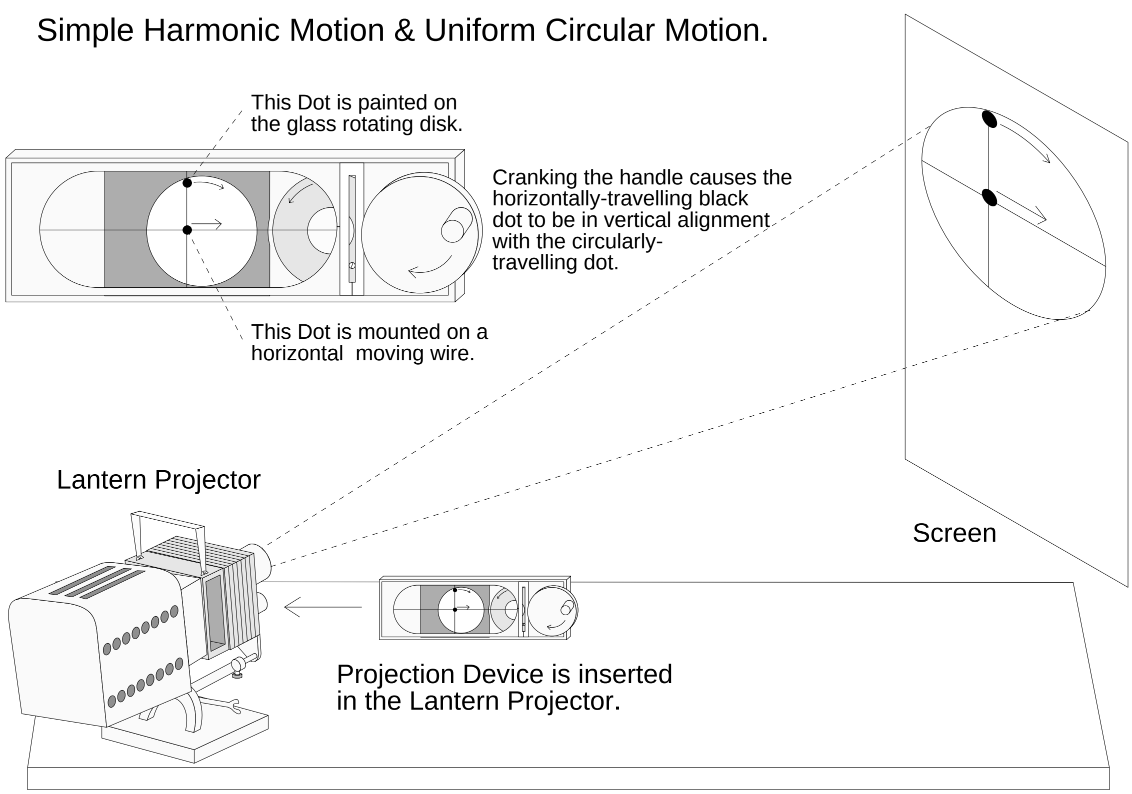
Lissajous Figures: Combination of Harmonic Motion.



Various different Lissajous figures on Overhead Transparencies taken from Mechanics, by Wm. F. Osgood, the MacMillian Co., N.Y. 1937, pg. 190-191

SIMPLE HARMONIC MOTION. **B+10+45**

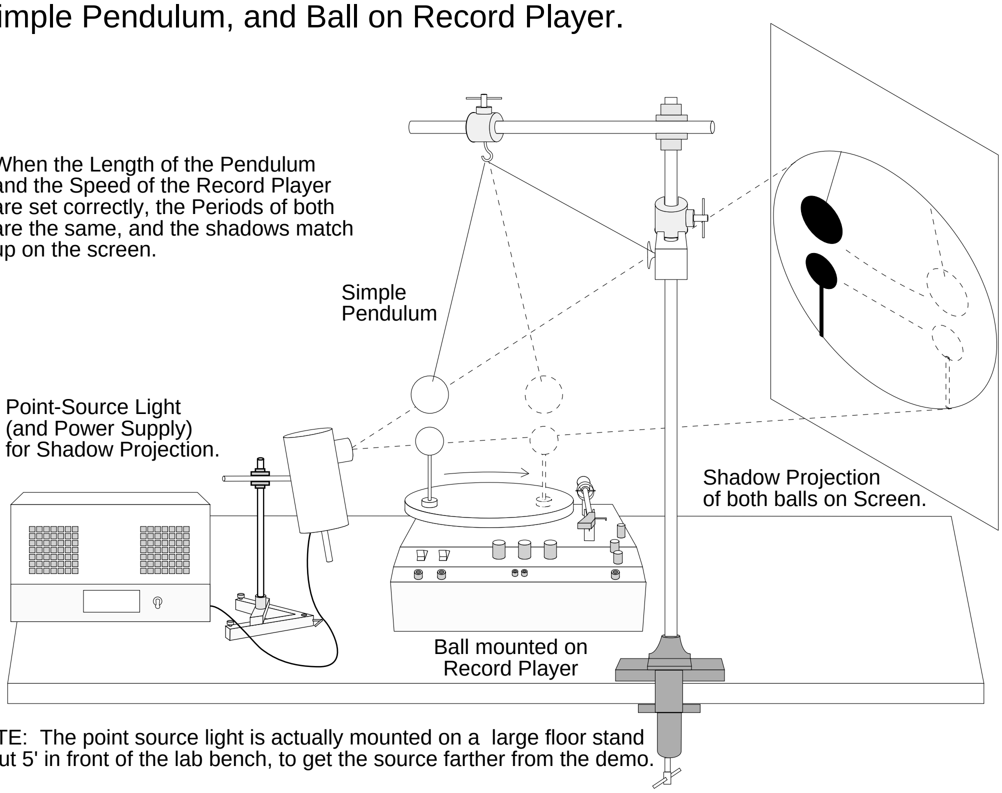
Simple Harmonic Motion & Uniform Circular Motion.



SIMPLE HARMONIC MOTION. B+10+50

Simple Harmonic Motion & Uniform Circular Motion:
Simple Pendulum, and Ball on Record Player.

When the Length of the Pendulum and the Speed of the Record Player are set correctly, the Periods of both are the same, and the shadows match up on the screen.

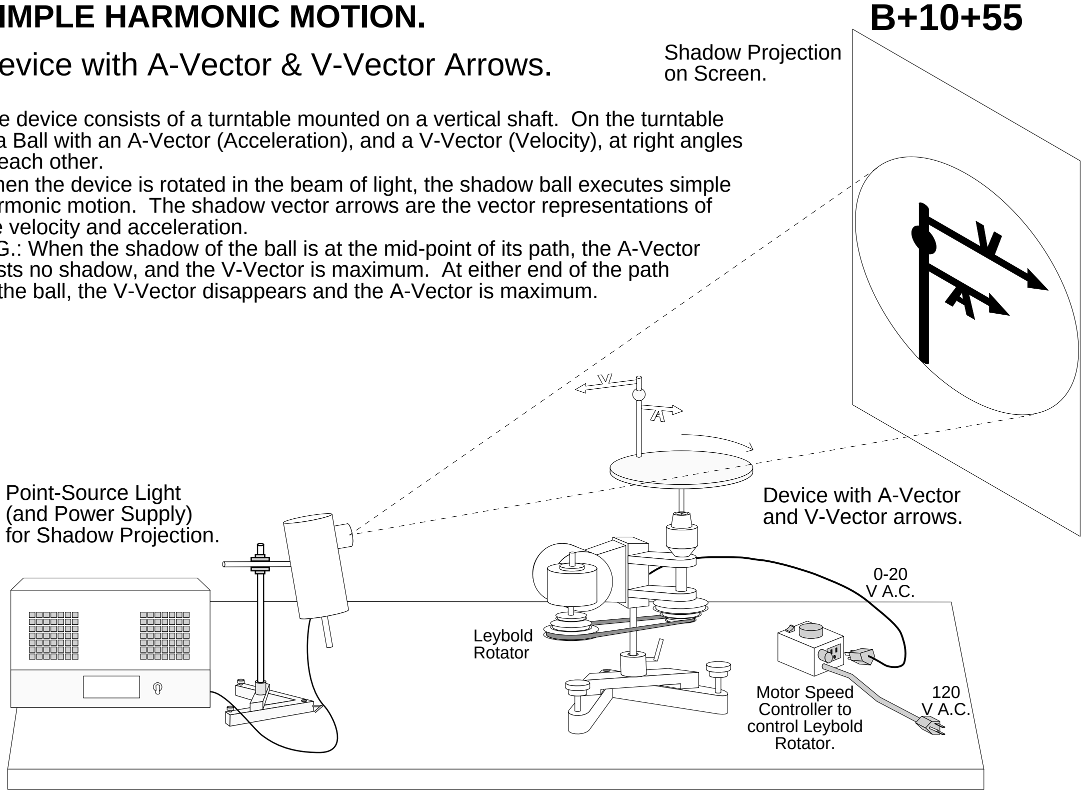


NOTE: The point source light is actually mounted on a large floor stand about 5' in front of the lab bench, to get the source farther from the demo.

SIMPLE HARMONIC MOTION. B+10+55

Device with A-Vector & V-Vector Arrows.

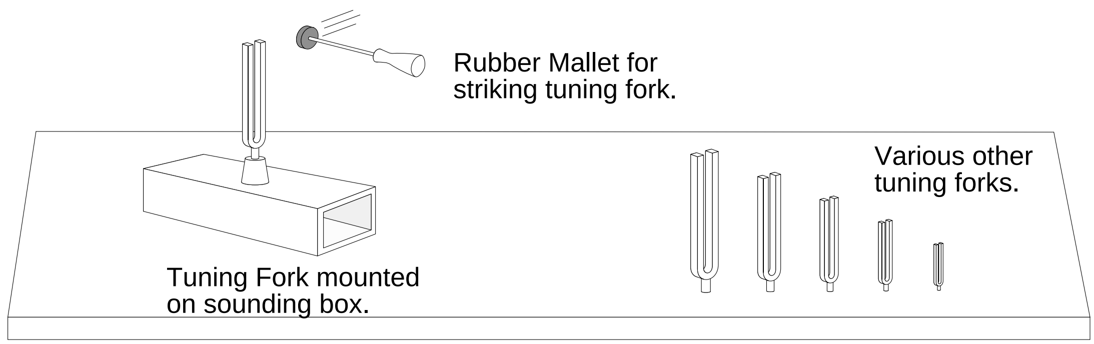
The device consists of a turntable mounted on a vertical shaft. On the turntable is a Ball with an A-Vector (Acceleration), and a V-Vector (Velocity), at right angles to each other.
When the device is rotated in the beam of light, the shadow ball executes simple harmonic motion. The shadow vector arrows are the vector representations of the velocity and acceleration.
E.G.: When the shadow of the ball is at the mid-point of its path, the A-Vector casts no shadow, and the V-Vector is maximum. At either end of the path of the ball, the V-Vector disappears and the A-Vector is maximum.



NOTE: The point source light is actually mounted on a large floor stand about 5' in front of the lab bench, to get the source farther from the demo.

SIMPLE HARMONIC MOTION. B+10+60

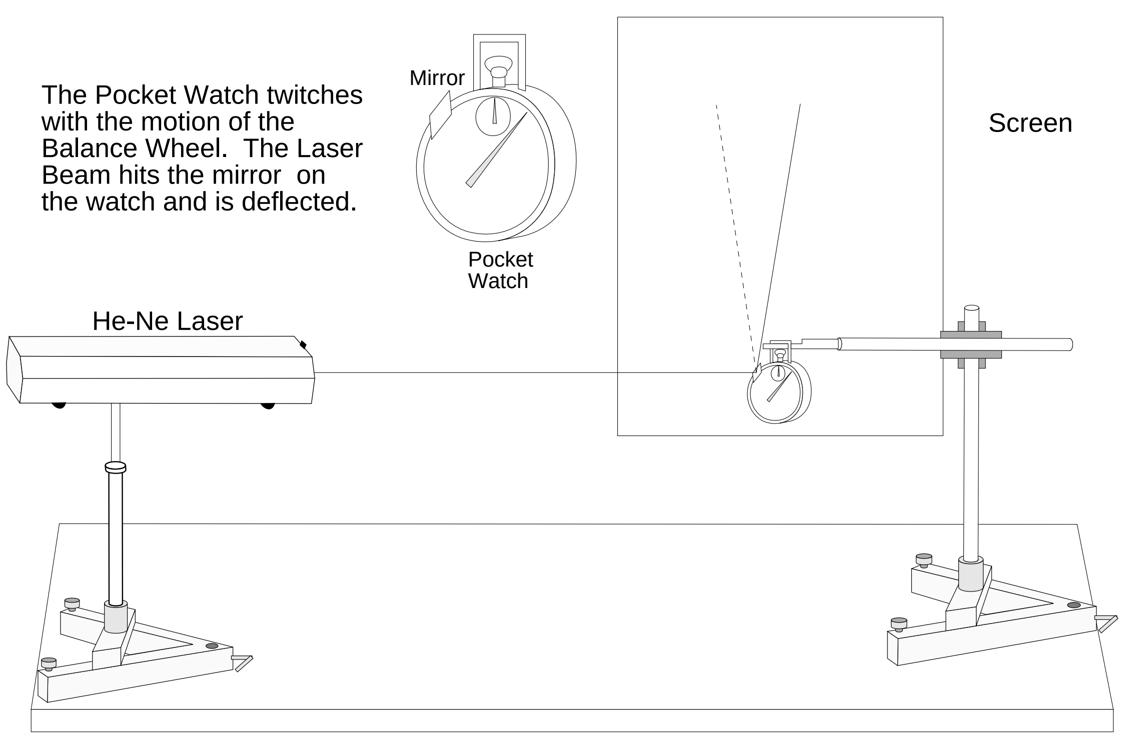
Tuning Forks.



SIMPLE HARMONIC MOTION. B+10+65

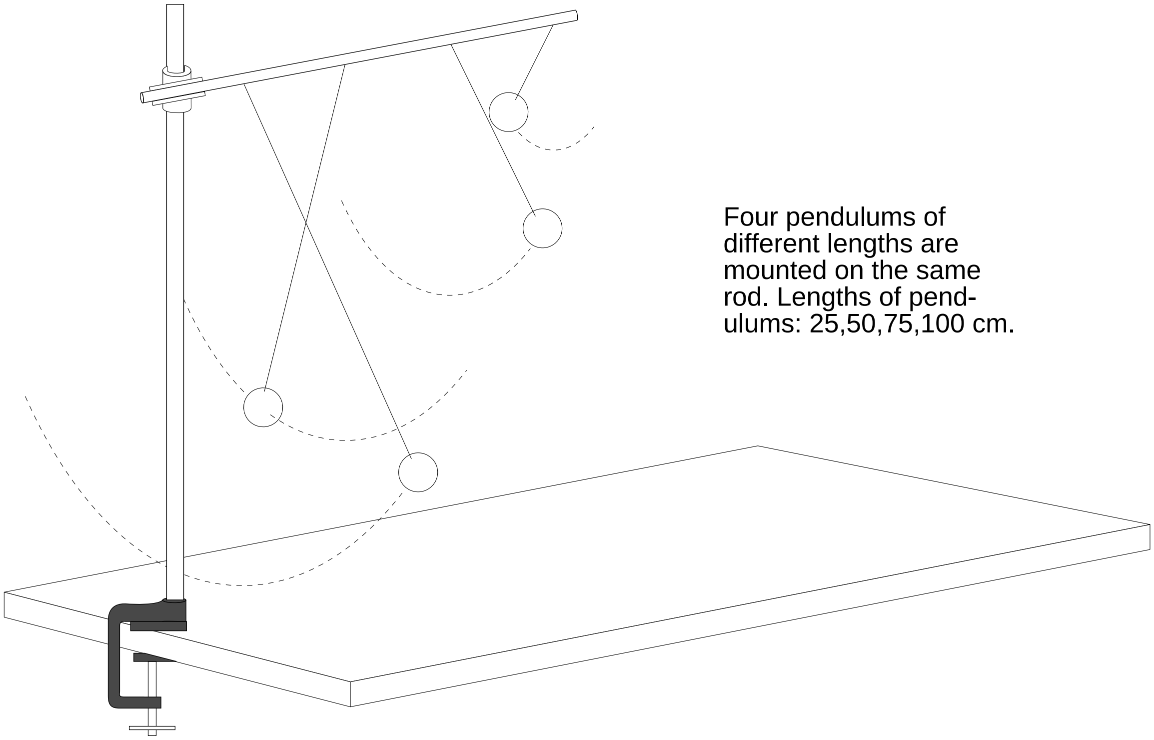
Laser Beam bouncing off Pocket Watch with mirror.

The Pocket Watch twitches with the motion of the Balance Wheel. The Laser Beam hits the mirror on the watch and is deflected.



SIMPLE HARMONIC MOTION. B+10+70

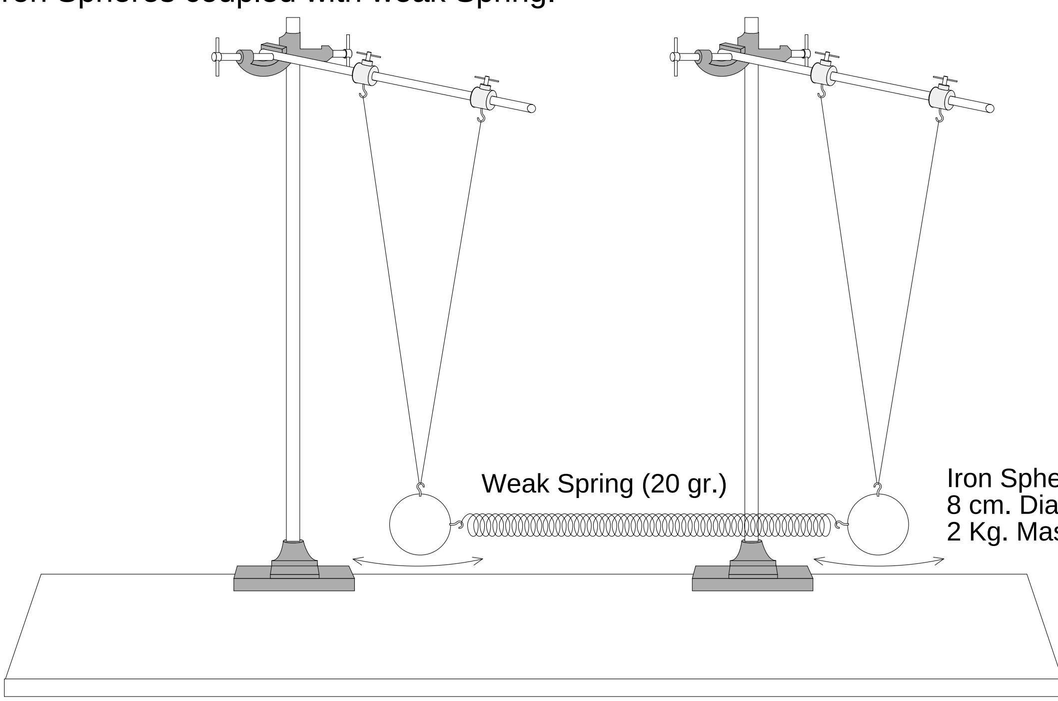
Four Pendulums: Same Mass, different Lengths.



Four pendulums of different lengths are mounted on the same rod. Lengths of pendulums: 25,50,75,100 cm.

COUPLED HARMONIC OSCILLATOR. B+15+0

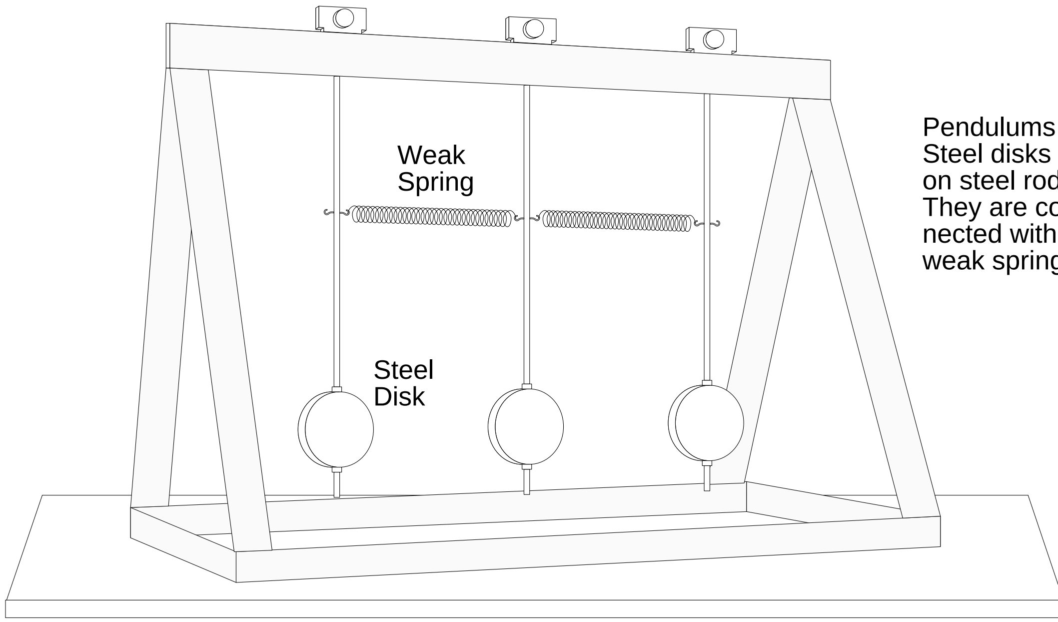
Iron Spheres coupled with weak Spring.



The behavior of two coupled harmonic oscillators may be shown with a pair of heavy iron spheres coupled with a weak spring. With the two suspensions tuned to the same frequency, couple the spheres with the spring to demonstrate the two normal modes: One in which they oscillate in phase, and one in which they oscillate 180 degrees out of phase.

COUPLED HARMONIC OSCILLATOR. **B+15+1**

Three Pendulums coupled with weak Spring.



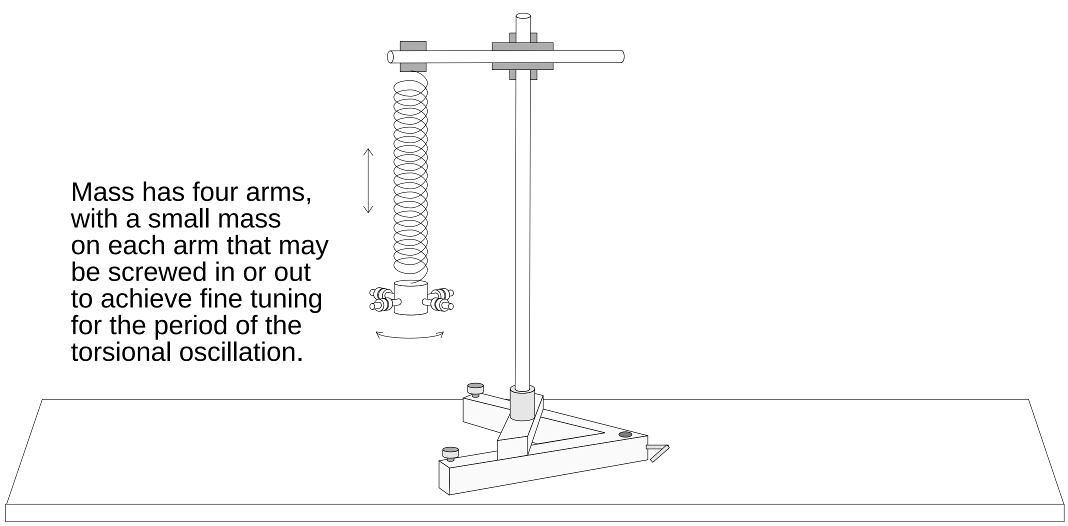
Pendulums are Steel disks on steel rods. They are connected with weak springs.

This is basically the same demo as B+15+0, except that 2 or 3 pendulums can be used.

COUPLED HARMONIC OSCILLATOR. **B+15+5**

Wilberforce Pendulum.

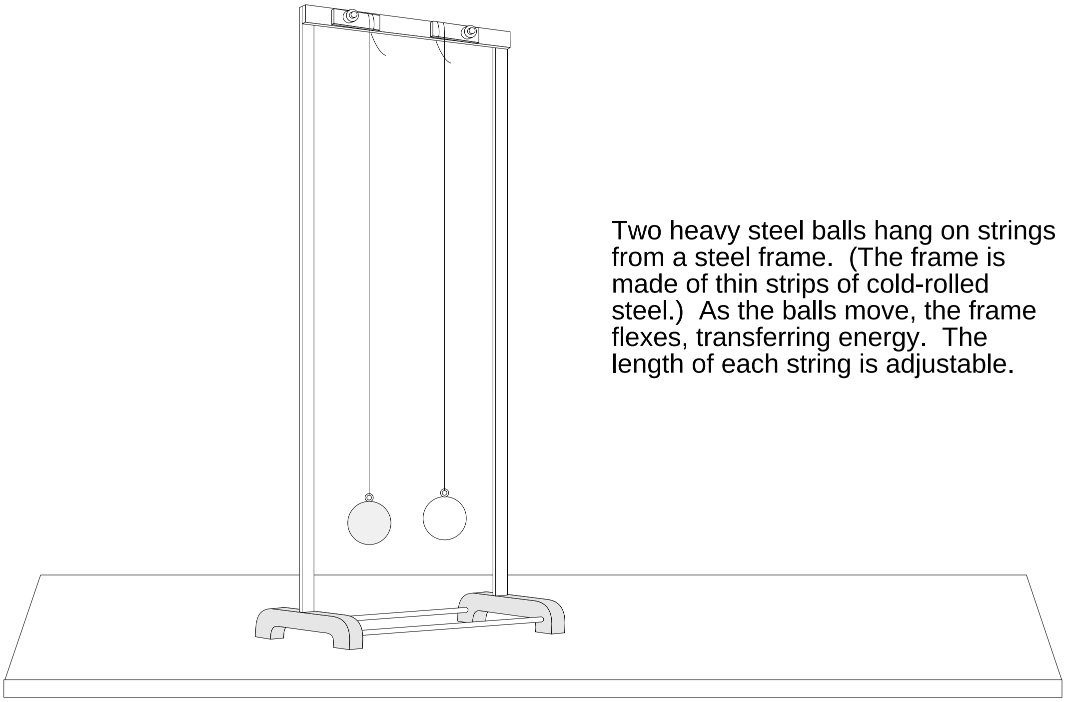
Mass has four arms, with a small mass on each arm that may be screwed in or out to achieve fine tuning for the period of the torsional oscillation.



This apparatus is designed so that the period of the up-and-down oscillation is nearly equal to the period of the torsional oscillation. Slowly, the apparatus switches between pure up-and-down mode to pure torsional mode.

COUPLED HARMONIC OSCILLATOR. **B+15+10**

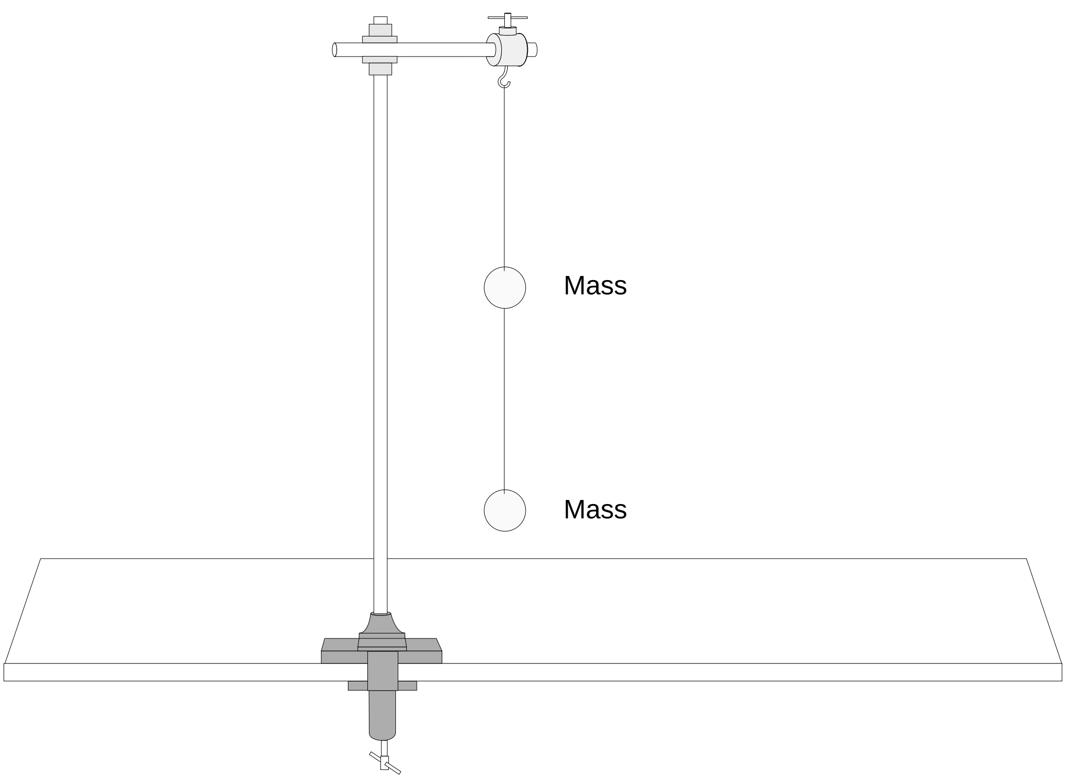
Two Pendulums on a flexible frame.



Two heavy steel balls hang on strings from a steel frame. (The frame is made of thin strips of cold-rolled steel.) As the balls move, the frame flexes, transferring energy. The length of each string is adjustable.

COUPLED HARMONIC OSCILLATOR. **B+15+15**

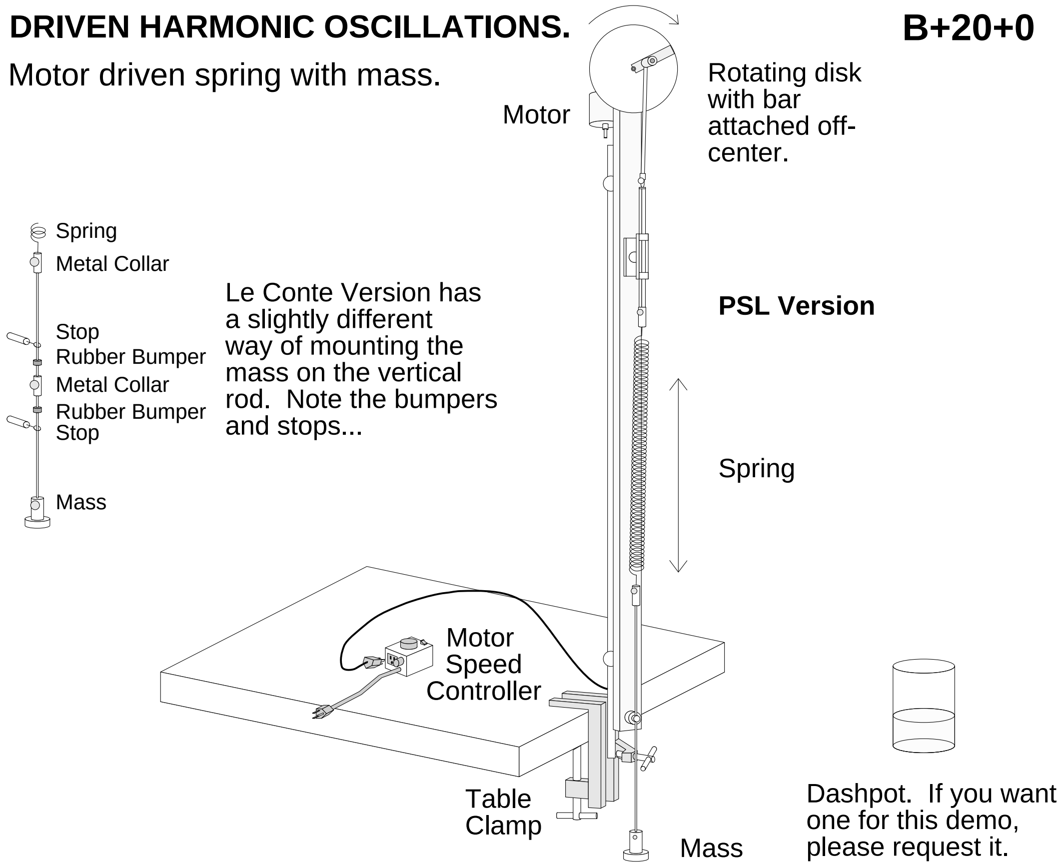
Two Pendulums hung on the same string.



DRIVEN HARMONIC OSCILLATIONS.

B+20+0

Motor driven spring with mass.

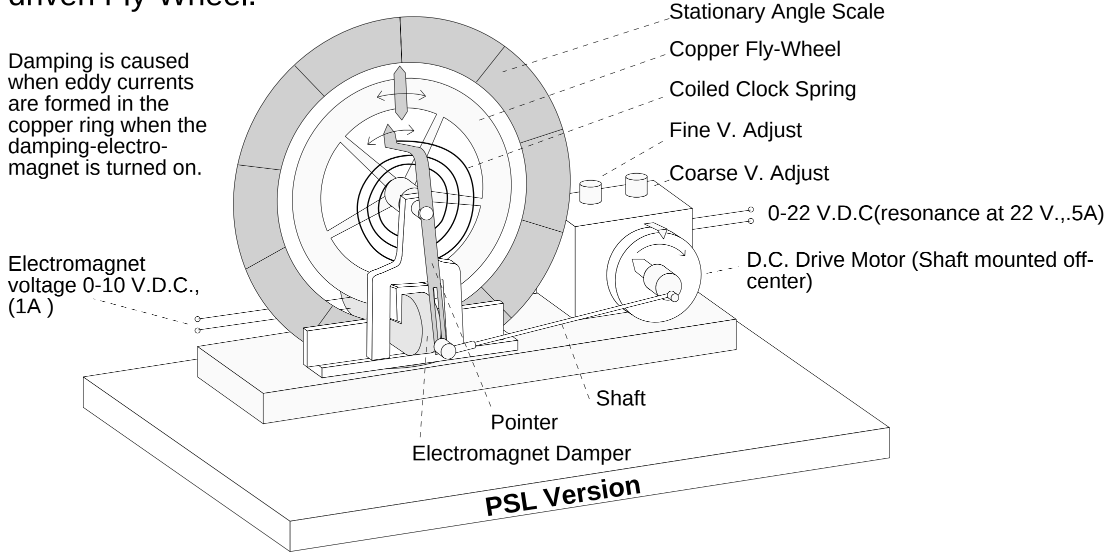


DRIVEN HARMONIC OSCILLATIONS.

B+20+5

Resonance and Damped Harmonic Motion of a driven Fly-Wheel.

Same apparatus as in B+10+25.



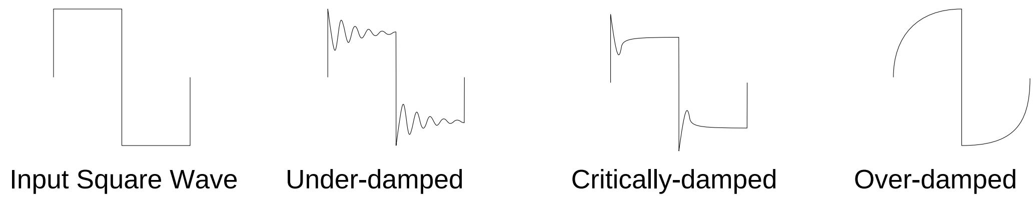
Drive Motor pushes Shaft, driving the Pointer back and forth,-pushing the Clock Spring which connects to the Copper Fly-Wheel. The amplitude of the swing of the fly-wheel depends on the frequency of the motor.

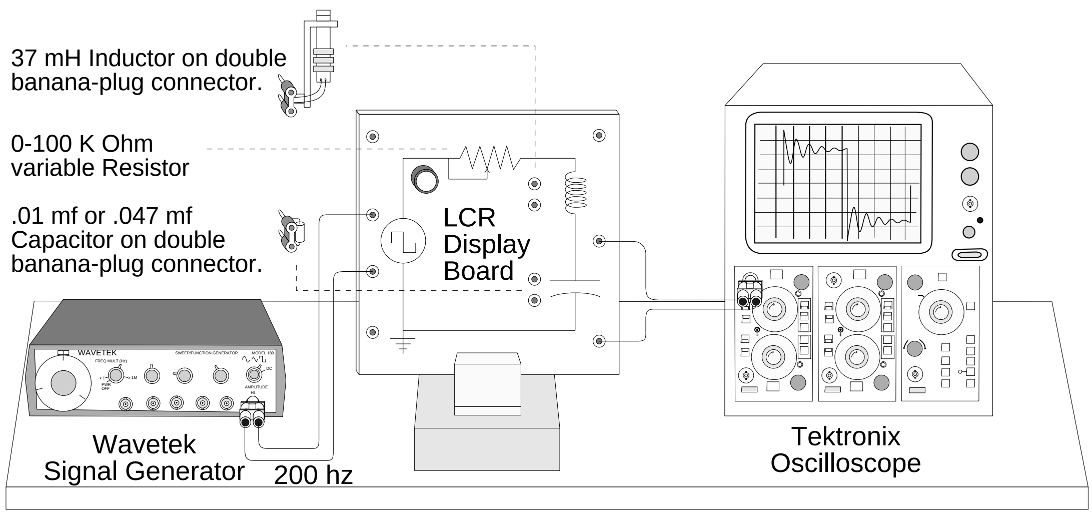
Note: There are two versions of this demo. The one at PSL is half the size of the one in Le Conte, but works better. The one in PSL can use portable D.C. Power supplies; Coarse and Fine Voltage controls are used to find resonance (1 sec. period).

The Le Conte Version is being modified to use A.C. power for the motor, and D.C. power for the damping electromagnet. For the D.C., the Ballast Resistance on the Control Panel must be adjusted. (2 sec. period).

DRIVEN HARMONIC OSCILLATIONS. B+20+10

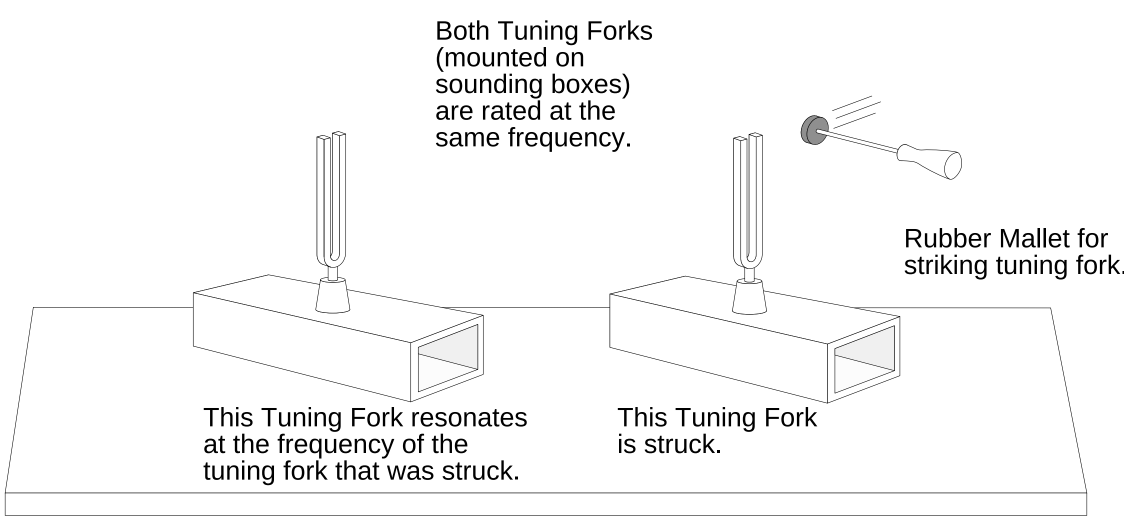
Damped Oscillations in a Resonant LCR circuit.





RESONANCE. B+20+15

Tuning Forks.



DRIVEN HARMONIC OSCILLATIONS. B+20+20

Film Loop: Tacoma Narrows Bridge Collapse Length(min.):4:40

Color: No Sound: No Note: This is also available in 16 mm Film: color, 4 Min.
Also on VHS Tape: color,4 Min.

The main span of the bridge near Tacoma, Washington was 2800 ft long, 39 ft wide, and the steel stiffening girders (shown during construction) were 8 ft tall. The bridge was opened for traffic on July 1, 1940. In the four months of active life of the bridge before failure, many transverse (vertical) modes of vibration were observed before November 7, 1940. The main towers were nodes, of course, and between them there were from 0 to 8 additional nodes. Maximum double amplitude (crest to trough) was about 5 ft in a mode with 2 nodes between the towers; the frequency of vibration at that time was 12 vib/min.

Measurements made before failure indicated that higher wind velocities favored modes with higher frequency. This correlation may be explained by the fact that turbulent velocity fluctuations of winds can be considered as composed of a superposition of many periodic fluctuations, and the fluctuations of higher frequency are preponderant at higher wind velocities. There was no correlation between wind velocity and amplitude of vibration. Early on the morning of November 7 the wind velocity was 40 to 45 mi/hr, perhaps larger than any previously encountered by the bridge. Traffic was shut down. By 9:30 a.m. the span was vibrating in 8 or 9 segments with frequency 36 vib/min and double amplitude about 3 ft. While measurements were under way, at about 10:00 a.m., the main span abruptly began to vibrate torsionally in 2 segments with frequency 14 vib/min. The amplitude of torsional vibration quickly built up to about 35° each direction from horizontal. The main span broke up shortly after 11:00 a.m. During most of the catastrophic torsional vibration there was a transverse nodal line at mid-span, and a longitudinal nodal line down the center of the roadway (the yellow center stripe!). Note that Prof. Farquharson sensibly strides (?) down the nodal line as he leaves the bridge after making observations.

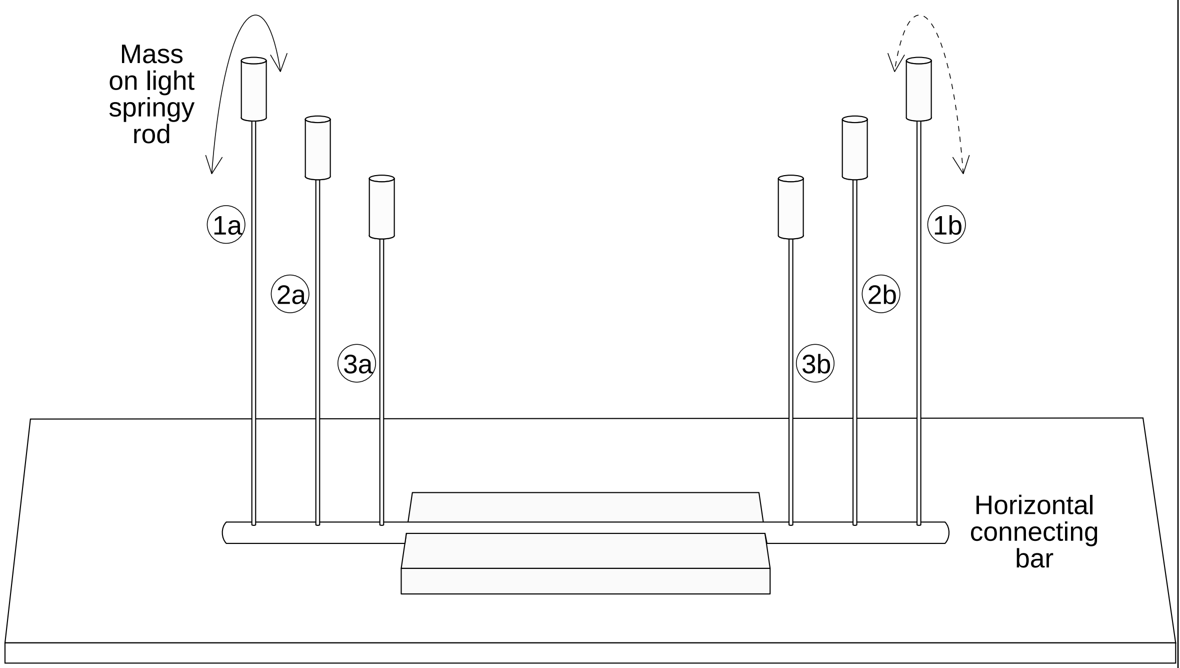
The crucial event at 10 a.m. which directly led to the catastrophic torsional vibration was apparently the loosening in its collar of the north cable by which the roadway was suspended. The center of the cable was moving back and forth relative to the center of the suspended span. This allowed the structure to twist. The wind velocity was close enough to the critical velocity for the torsional mode observed, and the vibration built up by resonance and was maintained until collapse inevitably took place.

The bridge was rebuilt using the original anchorages and tower foundations. Studies at the University of Washington Engineering Experiment Station resulted in a design for the new bridge which used deep stiffening trusses instead of girders. The new bridge is entirely successful.

HARMONIC RESONATOR. B+20+25

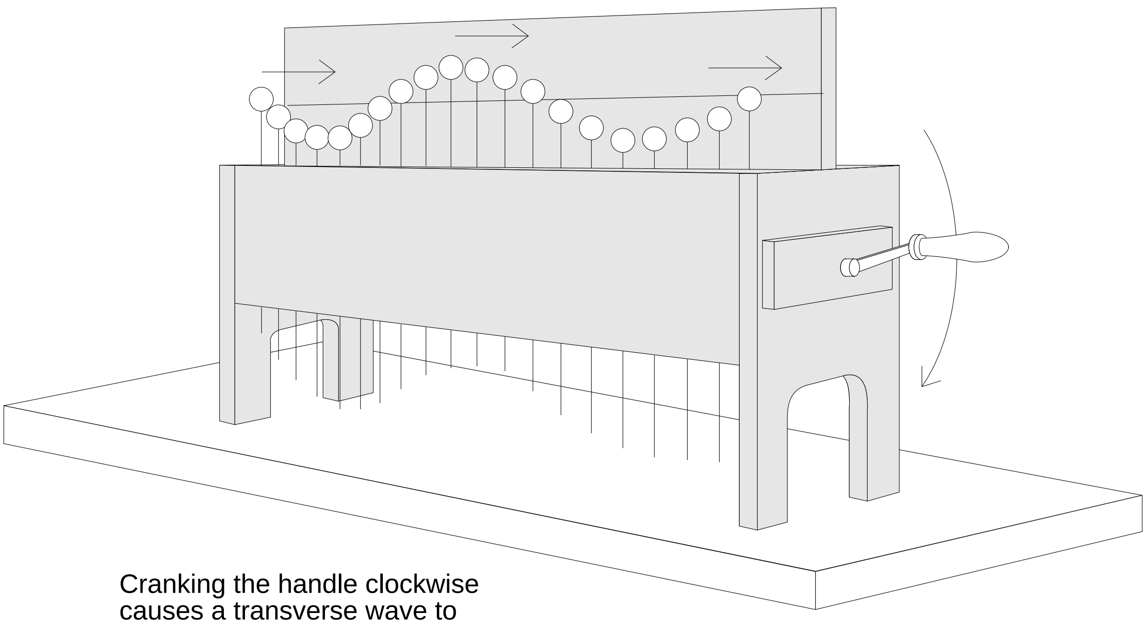
One oscillating mass on rod sets another mass on rod oscillating in resonance.

The apparatus consists of two sets of masses on light springy vertical rods. In a set, masses are all the same, but the rods differ in length. The two sets are weakly coupled by a horizontal bar. When mass 1a oscillates, mass 1b starts to oscillate in resonance (but 2a,2b,3a & 3b do not oscillate). When mass 2a oscillates, mass 2b oscillates in resonance, etc.



TRAVELLING WAVES IN ELASTIC MEDIA. B+25+0

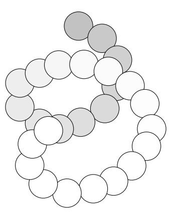
Machine Model for Transverse Waves.



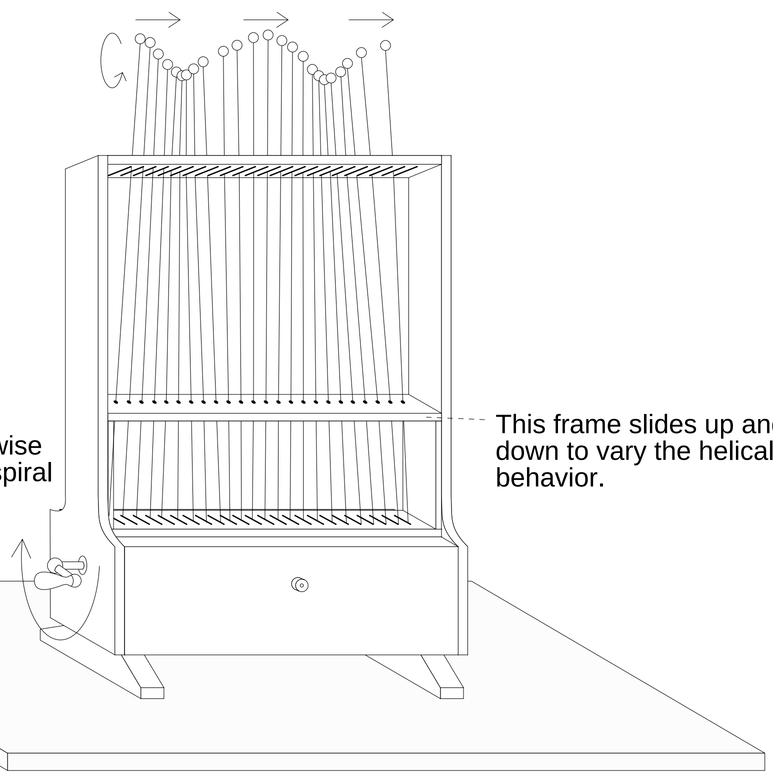
Cranking the handle clockwise causes a transverse wave to travel to the right.

TRAVELLING WAVES IN ELASTIC MEDIA. B+25+1

Adjustable Machine Model for Transverse Circular Waves.



End view of model shows helical nature of wave.

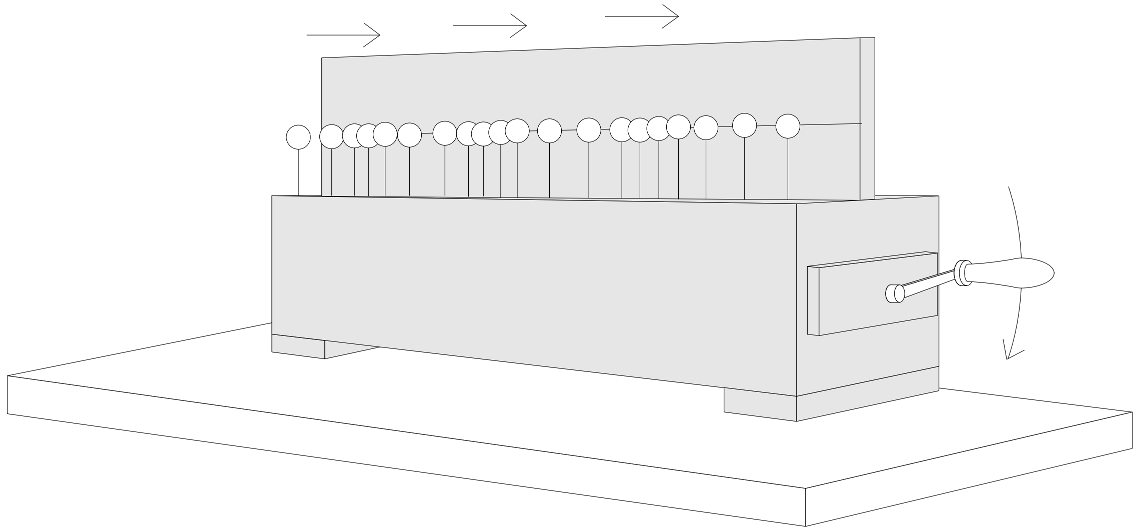


Cranking the handle clockwise causes a circular wave to spiral to the right.

This frame slides up and down to vary the helical behavior.

TRAVELLING WAVES IN ELASTIC MEDIA. B+25+5

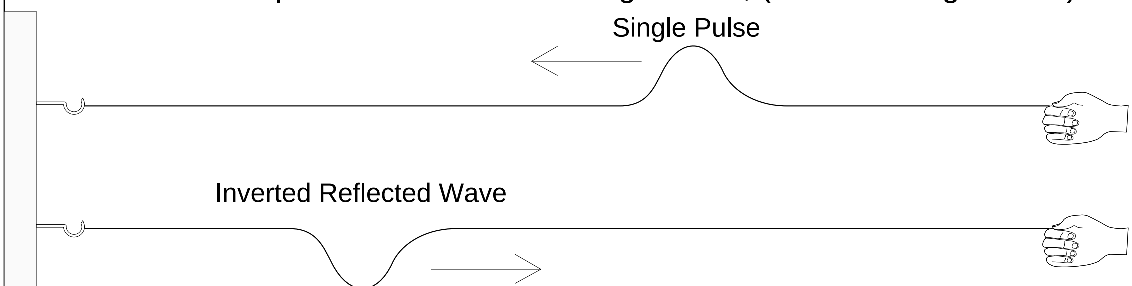
Machine Model for Longitudinal Travelling Waves.



Cranking the handle clockwise causes a longitudinal travelling wave to travel to the right.

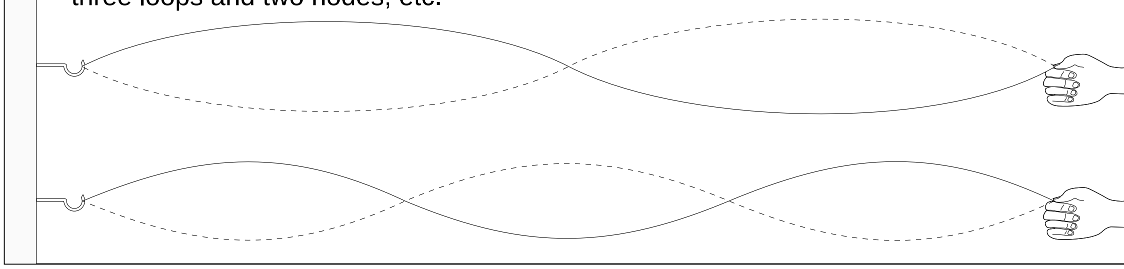
TRAVELLING WAVES IN ELASTIC MEDIA. B+25+10

The Rubber Rope: Transverse Travelling Waves, (and Standing Waves).



Attach one end of the rubber rope to the hook on the wall and stretch the rope across the front of the room. Quickly move the hand up or down once so as to give a pulse to the rope. (The rope should be fairly taut.) The pulse travels to the end and back again, being reflected from the stationary end without disturbing the wave motion.

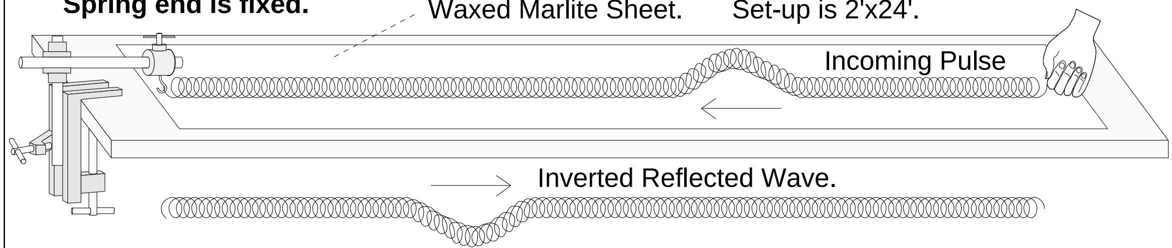
You may also use this rope to illustrate standing waves. Move the end periodically up and down with a slow motion; changing this period until the rope shows just two loops with a node in the center. Increase the up and down period to get three loops and two nodes, etc.



TRAVELLING WAVES IN ELASTIC MEDIA. B+25+15

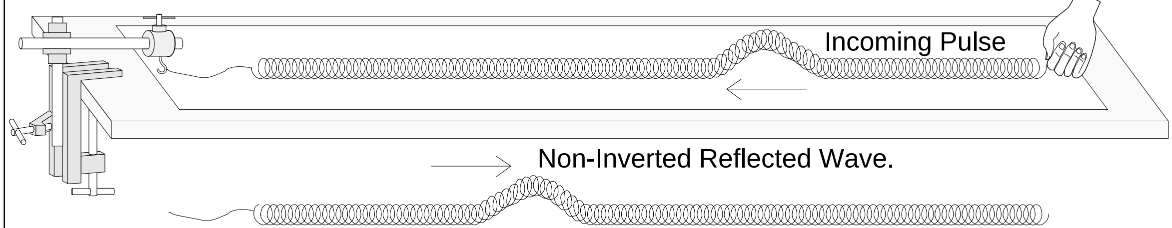
Long Flexible Spring: Transverse Travelling waves,Superposition,&Standing Waves.

Spring end is fixed.

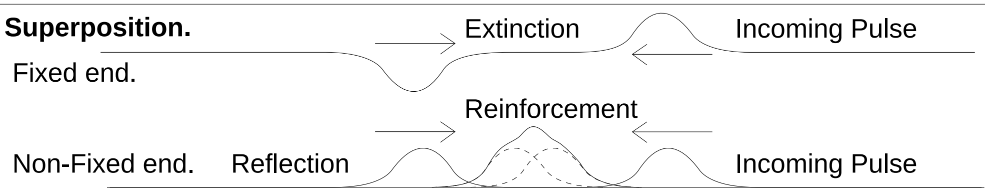


Note: Waves on the spring are slower than on the rubber rope in B+25+10...

Spring end is tied to a string (acting as if the spring end is not fixed).

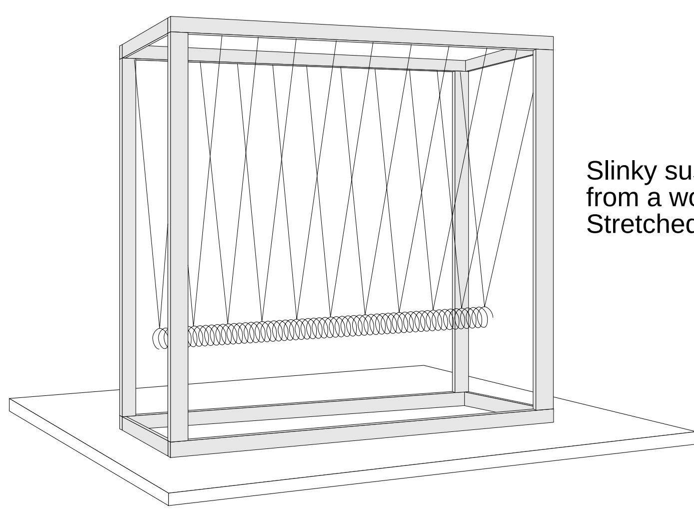


Superposition.

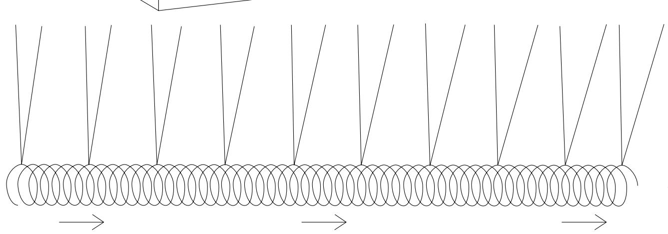


TRAVELLING WAVES IN ELASTIC MEDIA. B+25+20

Longitudinal Waves in a Suspended Slinky.



Slinky suspended on strings from a wooden frame. Stretched Slinky is 1 m. long.



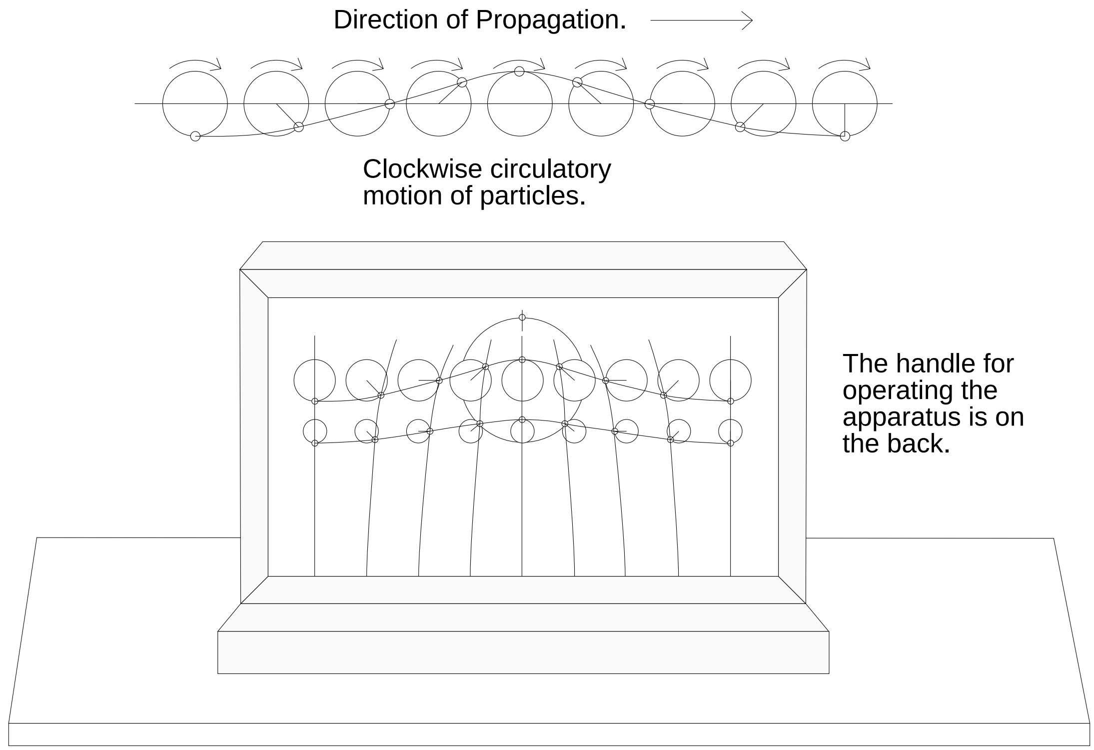
Slinky (9 cm. Diam.)

Striking one end of the spring with a palm sends a travelling longitudinal wave down the spring.

TRAVELLING WAVES IN ELASTIC MEDIA.

B+25+25

Mechanical Model of Water Waves: Circulatory Waves.

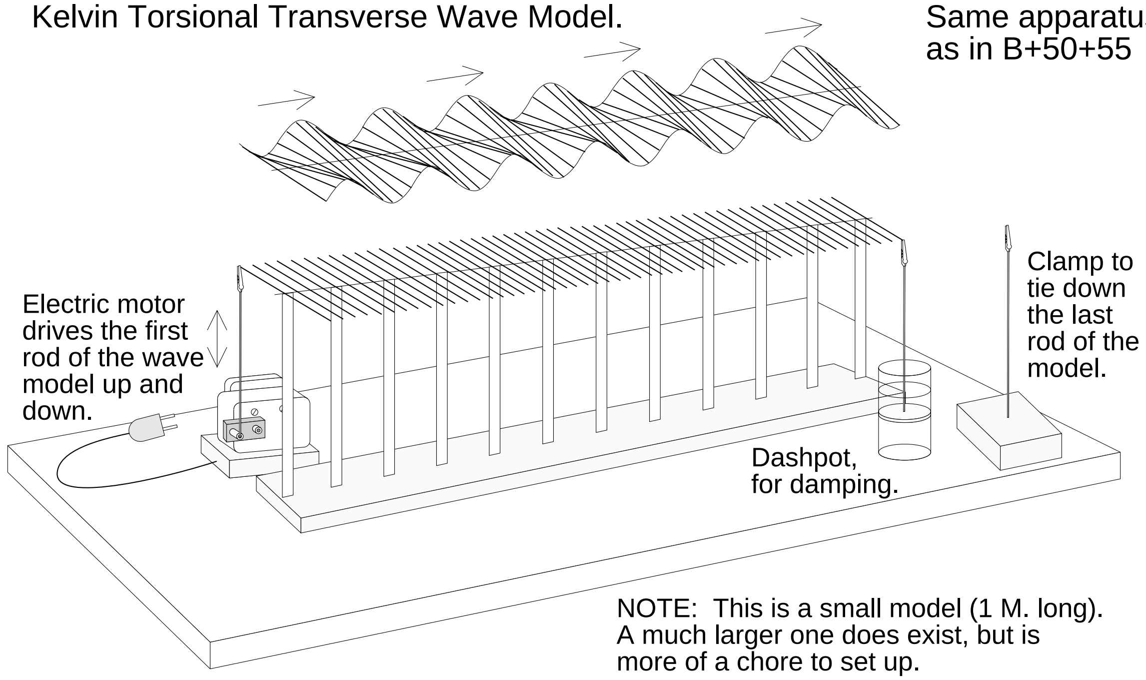


TRAVELLING WAVES IN ELASTIC MEDIA.

B+25+30

Kelvin Torsional Transverse Wave Model.

Same apparatus as in B+50+55



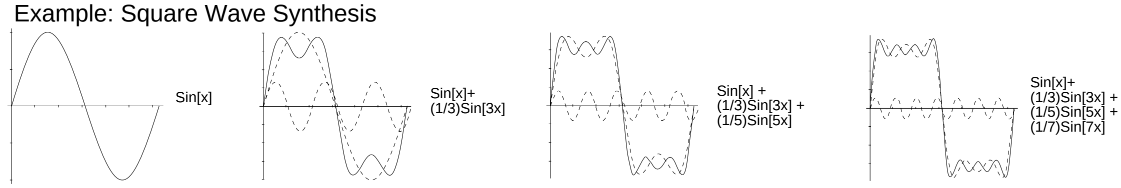
NOTE: This is a small model (1 M. long). A much larger one does exist, but is more of a chore to set up.

Light-weight rods are mounted ,in a parallel fashion, on a long piece of spring-steel wire. An electric motor can be used to introduce a periodic oscillation to one rod, and a transverse wave travels down the length of the apparatus. The opposite end can be free or tied down,-or connected to a dash-pot assembly for damping,-or connected to another model of different dimensions.

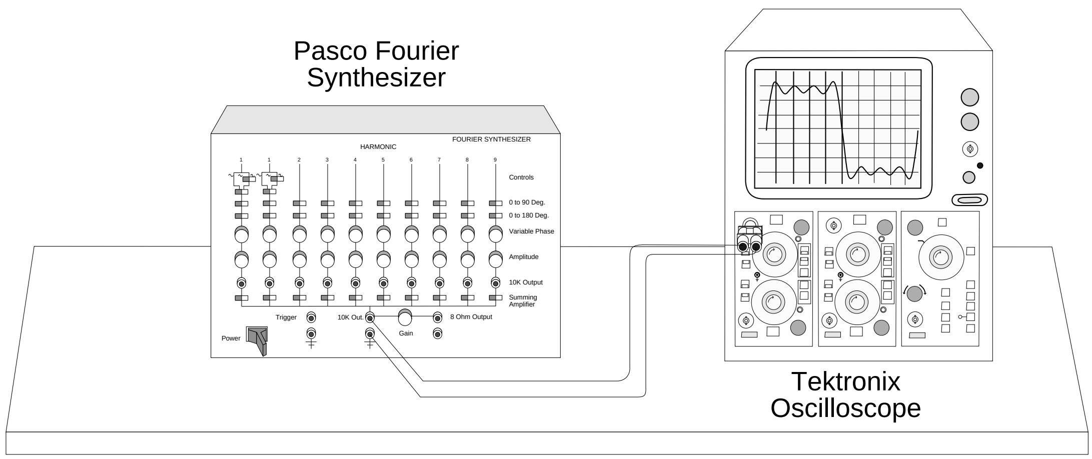
SUPERPOSITION OF WAVES. B+30+0

Fourier Series: The Pasco Fourier Synthesizer.

Example: Square Wave Synthesis

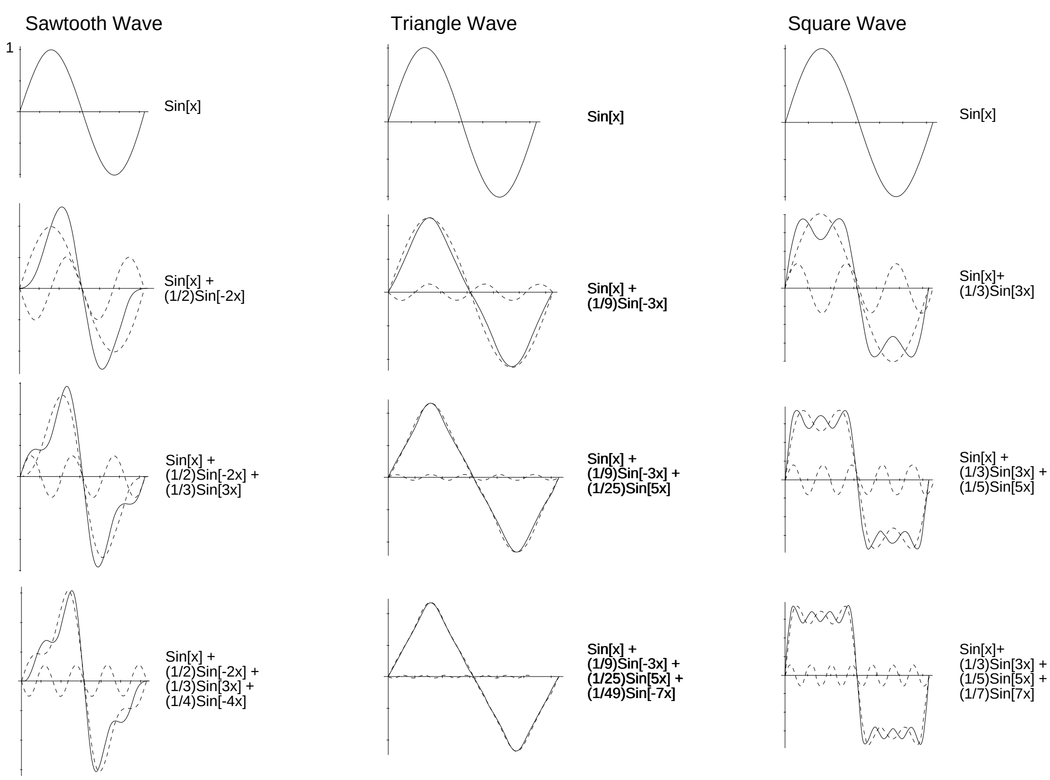


The Fundamental and harmonics can be added with appropriate phases and amplitudes to approximate Square Waves, Triangle Waves, Sawtooth waves, Pulses, etc.



SUPERPOSITION OF WAVES. B+30+1

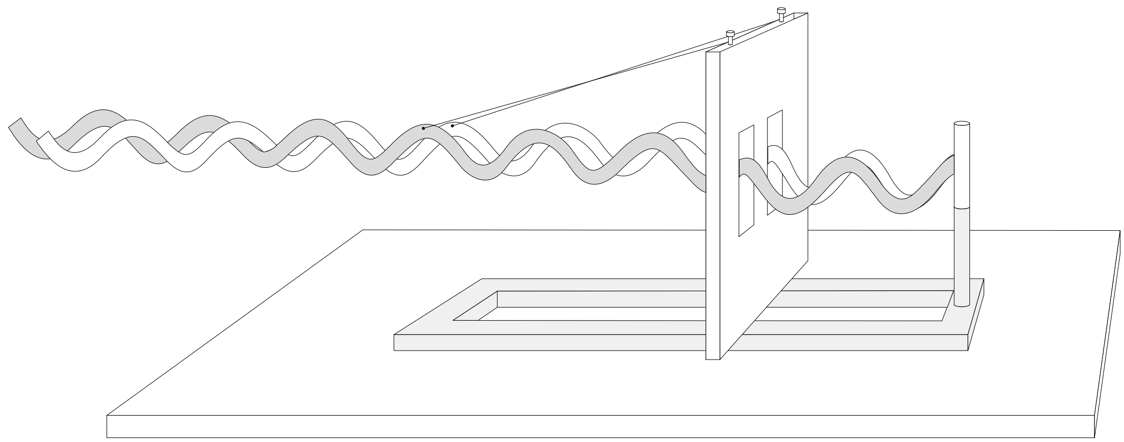
Fourier Superposition of Sine Waves to create waveforms. (OHP transparency)



INTERFERENCE. **B+35+0**

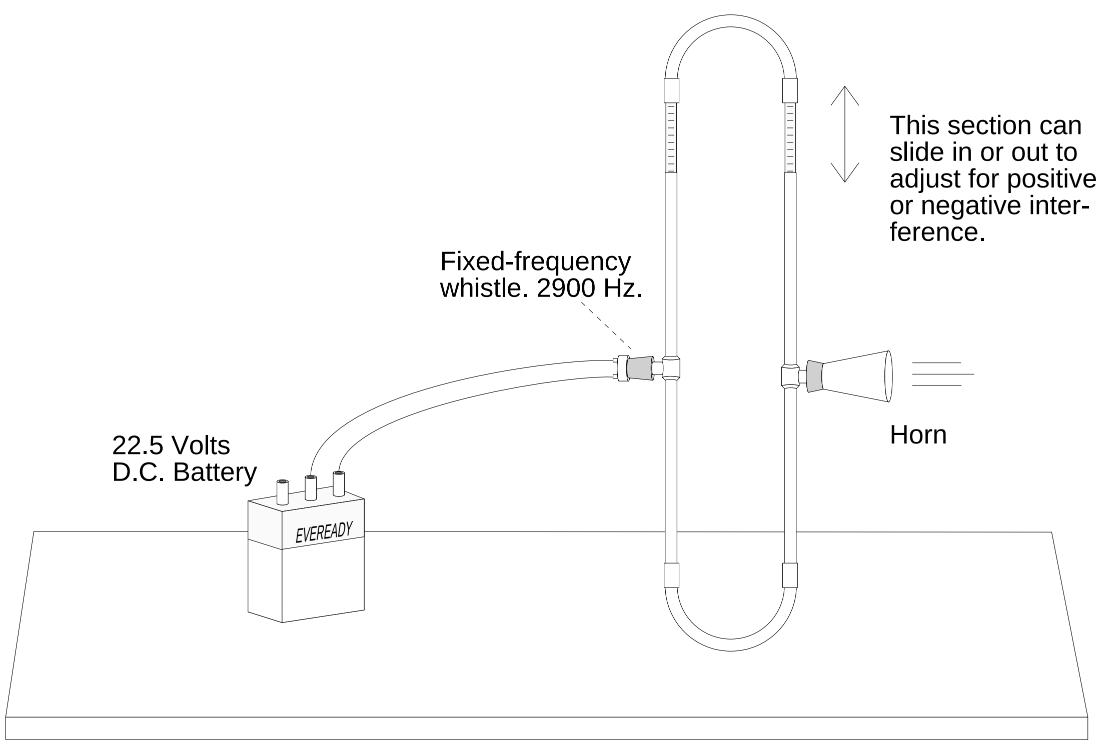
Sound Waves: 2 source interference,- a wooden mechanical model.

The model is made of plywood. The two 'waves' are hinged and suspended so that they can be moved independently. Note: There are 'waves' of different frequency that can be mounted.



INTERFERENCE. **B+35+5**

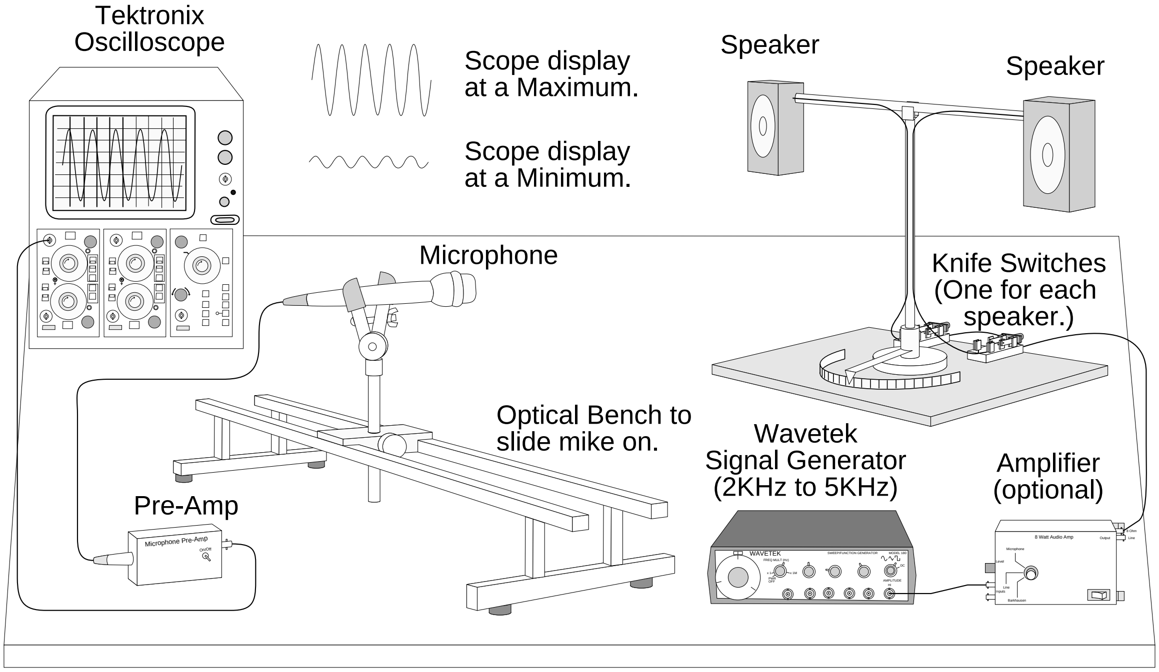
Acoustic Interferometer: Interference with the Quincke Tube.



INTERFERENCE. B+35+10

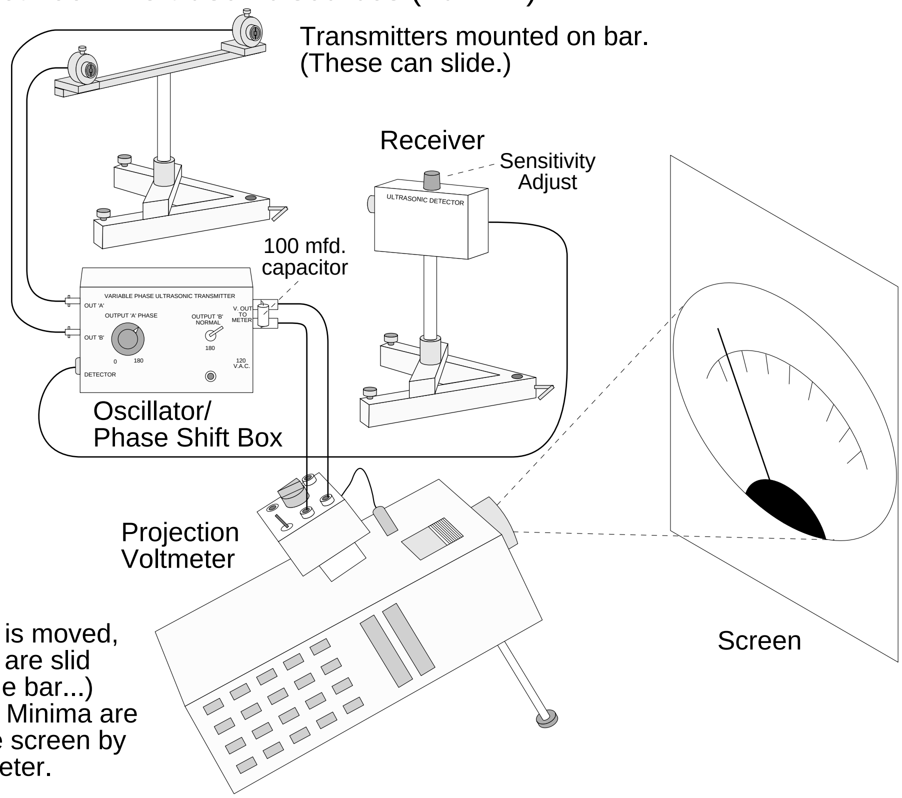
Interference of Sound Waves from 2 Sources.

The Speaker Assembly is swung left or right (or, the Mike is moved left or right), and the amplitude of the sound is displayed on the scope. Switches on the base of the speaker unit allow either speaker to be turned on or off, or the phase to be reversed with respect to each other. Distance between speakers and mike is about 1 M.



INTERFERENCE. B+35+12

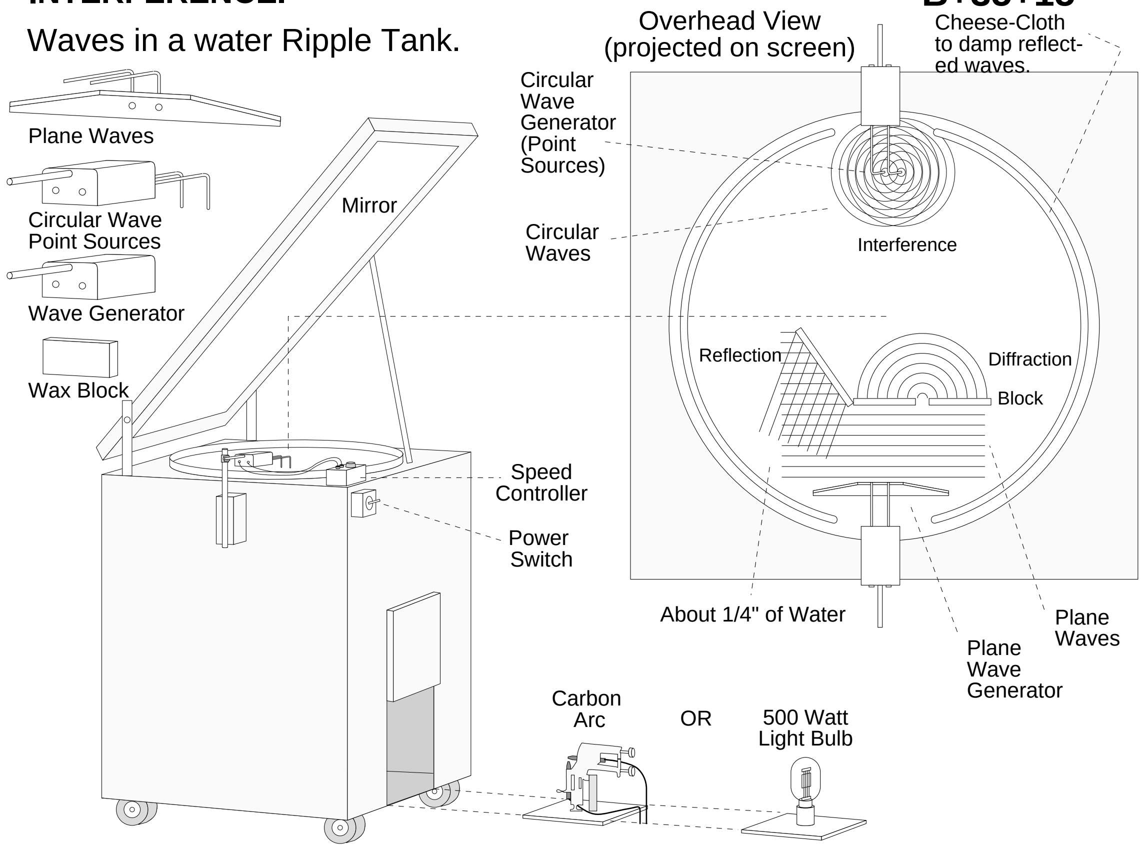
Interference between 2 Ultrasonic sources (40 KHz).



As the Receiver is moved, (or Transmitters are slid left or right on the bar...) the Maxima and Minima are displayed on the screen by the projection meter.

INTERFERENCE. **B+35+15**

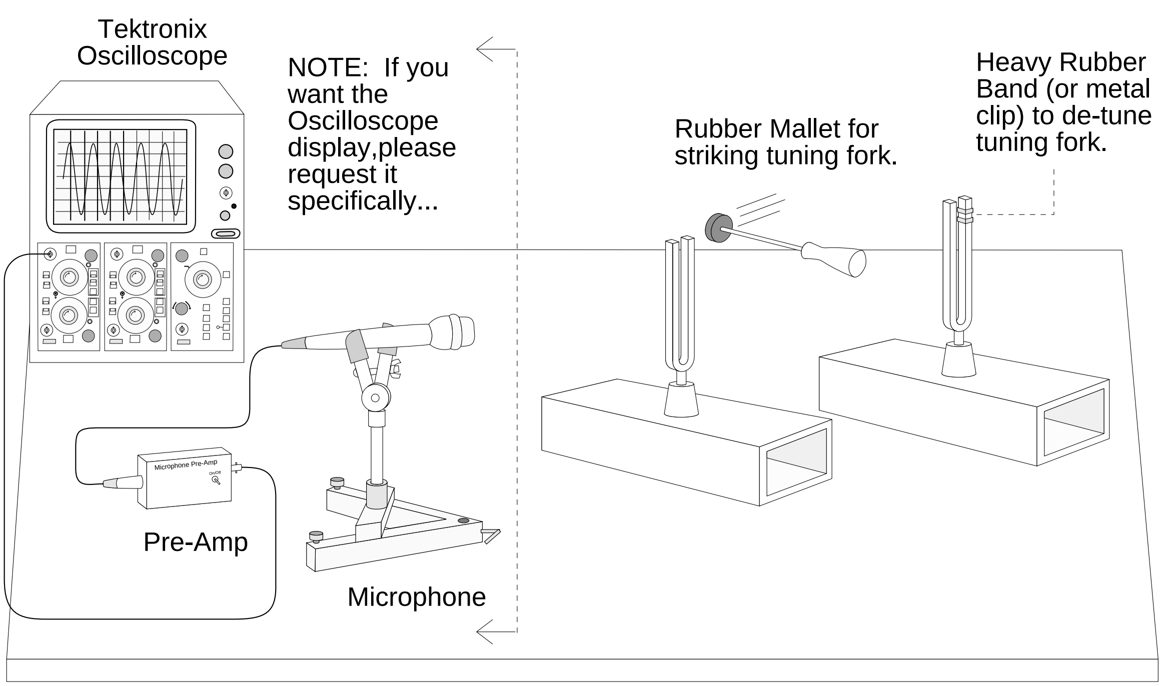
Waves in a water Ripple Tank.



INTERFERENCE. **B+35+20**

Beats with Tuning Forks.

Both Tuning Forks (mounted on sounding boxes) are rated at the same frequency. One fork is slightly de-tuned with a rubber band or metal clip. Both forks are struck, and beats result.

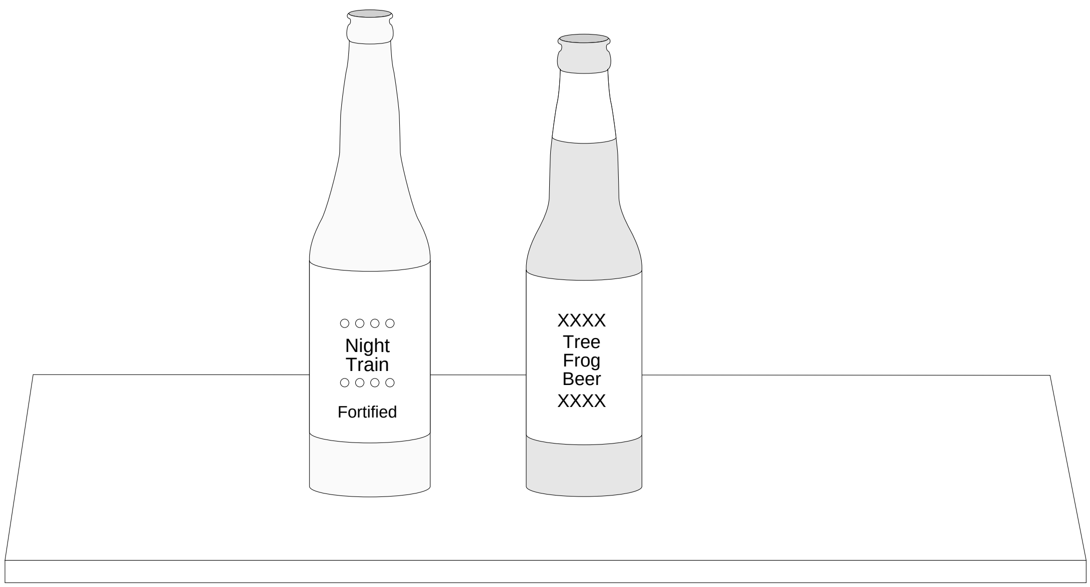


INTERFERENCE. B+35+25

Beats using two glass bottles.

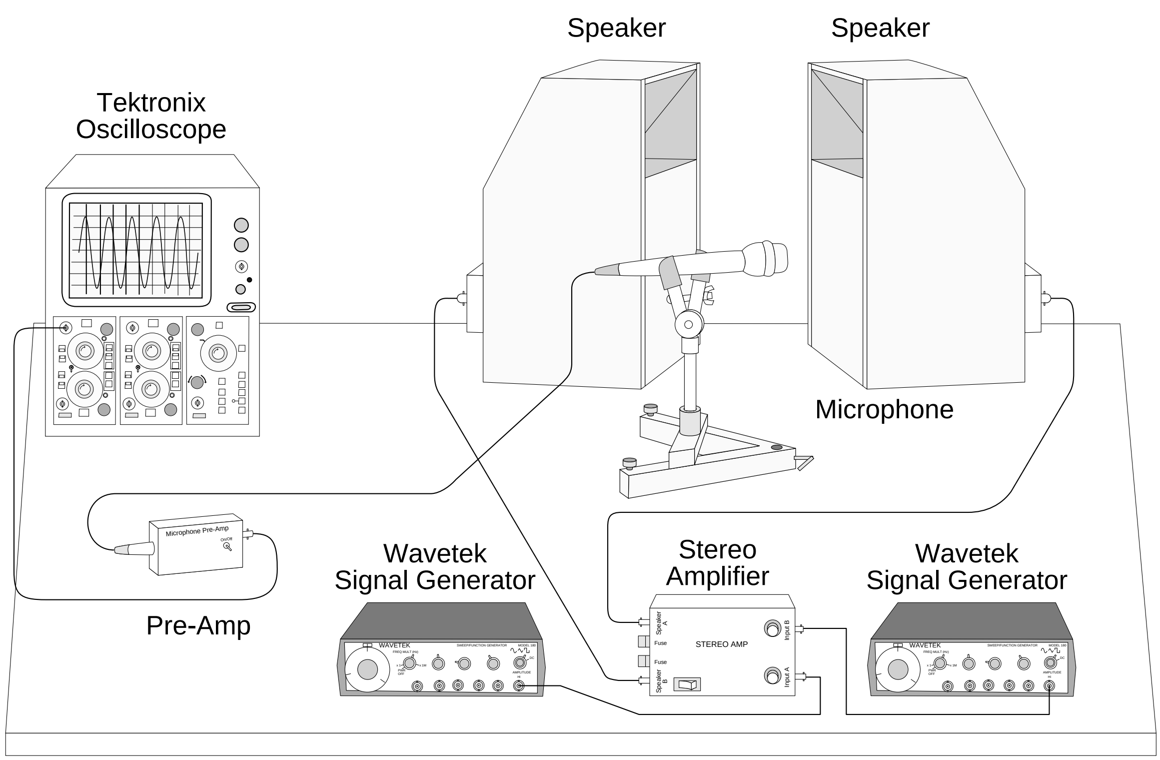
This demonstration requires two long-winded volunteers. The volunteers must hold the bottles as close together as humanly possible,and achieve both a loud and sustained volume.

NOTE: It is also possible to arrange a compressed-air nozzle at a suitable angle over the top of each bottle in order to produce the beats.



INTERFERENCE. B+35+30

Acoustical Beats from two Speakers,-observed on Oscilloscope.



INTERFERENCE. B+35+35

Film Loop: Multiple Slit Diffraction Length (min.):3:25

Color: No Sound: No Note: This is also available on videotape.

The interference pattern of two narrow slits is shown to be similar to that produced by two point sources; the wavelengths are the same, and the slit separation equals the source separation. Using 2, 3, 4, and finally 8 narrow slits, the interference maxima are shown to become stronger directional beams; i.e. the wave fronts become straight. The zero and first order beams are emphasized by shading portions of the pattern.

APPARATUS. A long vibrating bar was used to generate the periodic straight waves. An abnormally large wave amplitude was generated so that the diffracted wave on the far side of the slits was easily visible. The water depth was about 0.8 inch. The metal barrier protruded above the water surface.

DATA AND NOTES. The angular positions of the maxima and minima for all patterns shown (2, 3, 4 and 8 slits) are the same as those of the interference pattern from two point sources which have the same wavelength and a source separation equal to the separation of the slits; first maxima at about 50° and ratio l/d = 0.75. The slits were narrow enough (about half the wavelength) so that there were no diffraction nodes, but the intensity of the diffracted wave decreased with increasing angle, up to 90°. Therefore, the interference pattern from the multiple slits is quite weak at large angles from the normal, whereas the pattern from two point sources is strong at large angles. Even with only 8 slits in the "grating", the interference maxima are developed into very nearly non-diverging beams which head in the direction of the maxima of the double-slit pattern.

In order to prevent stroboscopic effects in the projected picture the sequences were photographed with a high speed camera; the projected phenomena are slowed down by about a factor of 3.

INTERFERENCE. B+35+40

Film Loop: Single Slit Diffraction Length (min.):3:30

Color: No Sound: No Note: This is also available on videotape.

With the slit width held constant, the wavelength is first decreased from about the size of the slit width to 1/4 that length, and is then increased again to the original wavelength. Next, holding the wavelength constant, the slit width is increased from slightly greater than the wavelength to about 5 times that width. In the last sequence the slit width is about 15 times the wavelength.

APPARATUS. A long vibrating bar was used to generate the periodic straight waves. An abnormally large wave amplitude was generated so that the diffracted wave on the far side of the slit was easily visible. The water depth was about 0.8 inch. The metal barrier protruded above the water surface.

NOTES. In the diffraction pattern, as in interference phenomena (see Film-Loop 80-240), the positions of nodes and maxima depend on both the slit width and the wavelength. In the last sequence one sees strong straight wave fronts beyond the slit, and the diffraction effects are relatively less significant. Even if the slit were very much wider than shown, there would still be diffraction effects at the edge of the slit; see Film-Loop 80-244. Multiple slit diffraction is shown in Film-Loop 80-243.

In order to prevent stroboscopic effects in the projected picture the sequences were photographed with a high speed camera; the projected phenomena are slowed down by about a factor of 3.

INTERFERENCE. B+35+45

Film Loop: Interference of Waves. Length (min.):4:00

Color: No Sound: No Note: This is also available on videotape.

An interference pattern is produced by two sources vibrating in phase. At one point the motion is frozen, and superposed marks identify the source separation and the wavelength of the periodic waves. A fixed reference mark is superposed on one of the first order maxima. Then the source separation is doubled without changing the wavelength; the mark now lies on a second order maximum in the new interference pattern. Next, keeping this separation the same, the wavelength is doubled; the fixed mark again lies on a first order maximum of the interference pattern. In the last sequence the interference pattern is slowly changed by continuously decreasing the wavelength.

APPARATUS. The water depth was about 0.8 inch, but was not critical. The periodic circular waves were produced by magnetically vibrating small spheres on the water surface; small electromagnets placed underneath the tank activated the floating spheres.

DATA.	First sequence	d = 6 cm;	l = 2 cm
	Double separation	d = 12 cm;	l = 4 cm
	Double wavelength	d = 12 cm;	l = 4 cm

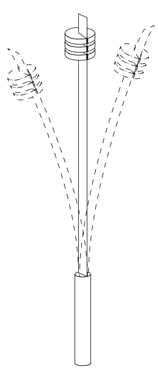
NOTES. The principal emphasis in the film is to show the dependence of the interference pattern on the wavelength and source separation. Other related demonstrations of interference phenomena are shown in Film-Loops 80-239 and 80-241.

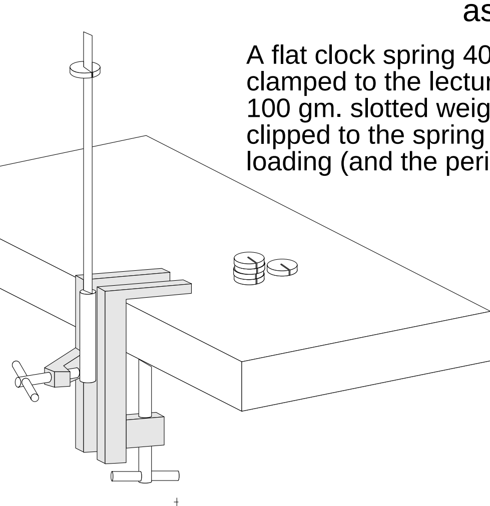
In order to prevent stroboscopic effects in the projected picture the sequences were photographed with a high speed camera; the projected phenomena are slowed down by about a factor of 3.

SOUND SPECTRUM/SOURCES. B+45+0

InfraSound: not audible.

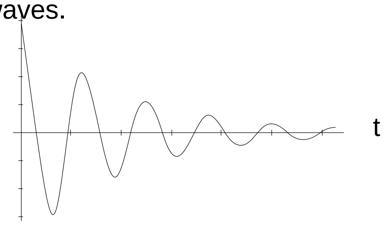
Same apparatus as B+10+30



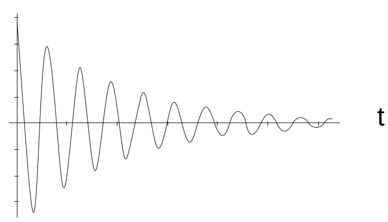


A flat clock spring 40 cm. long is clamped to the lecture table.
100 gm. slotted weights can be clipped to the spring to vary the loading (and the period).

The spring steel pendulum vibrates under 10 Hz,-thus is not audible, but compresses the air and produces pressure waves.



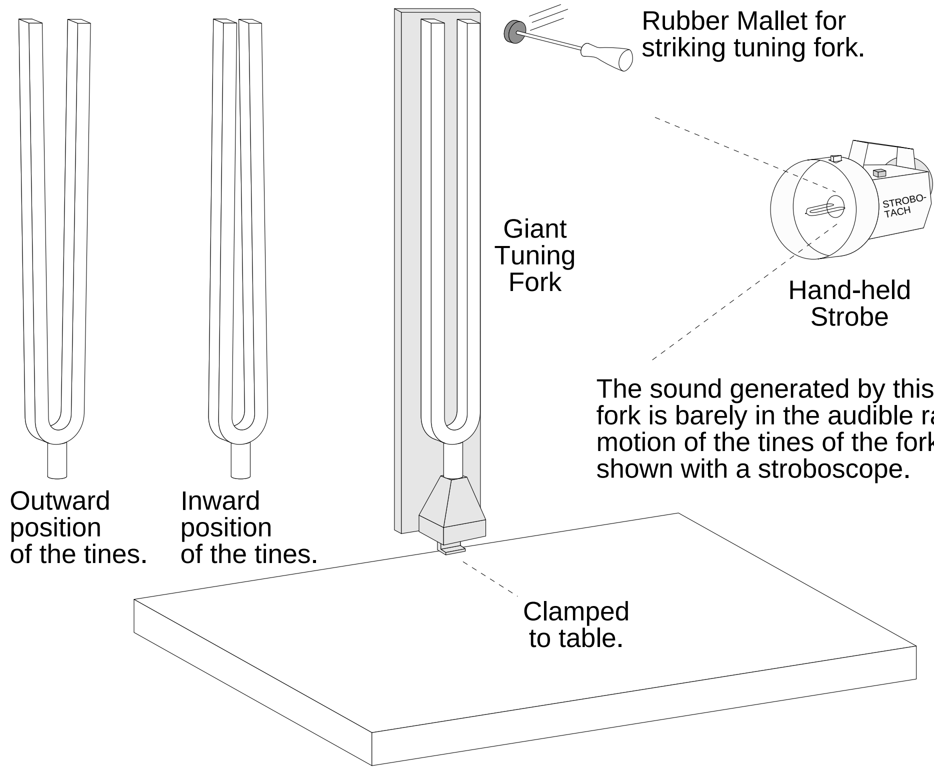
More Mass clipped to Spring.



Less Mass clipped to Spring.

SOUND SPECTRUM/SOURCES. B+45+5

InfraSound: Giant Tuning Fork,-barely in audible range.



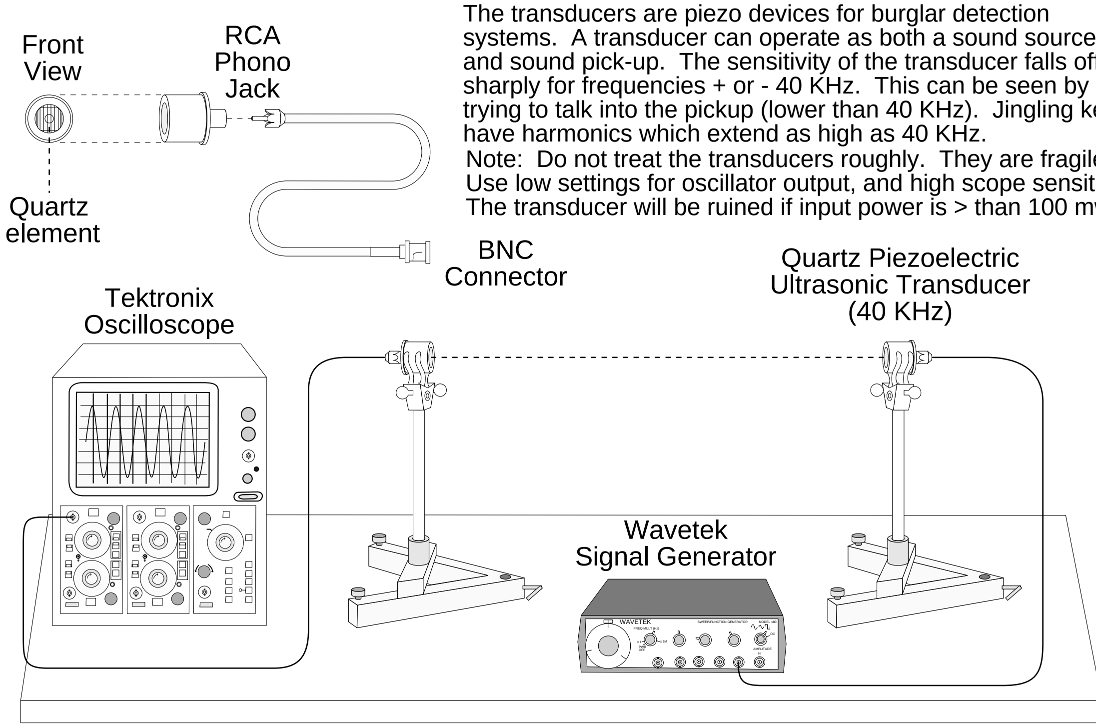
The sound generated by this giant tuning fork is barely in the audible range. The motion of the tines of the fork can be shown with a stroboscope.

SOUND SPECTRUM/SOURCES. B+45+10

Ultrasound: Pair of transducers.

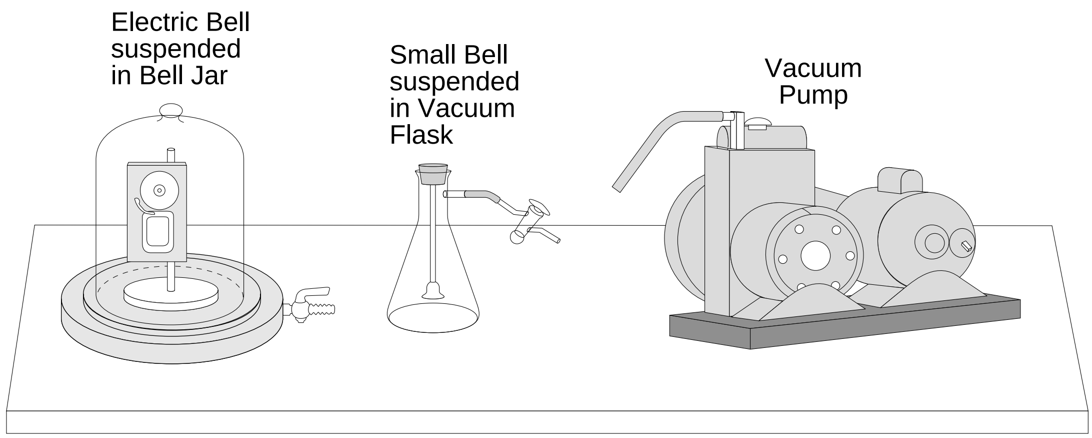
The transducers are piezo devices for burglar detection systems. A transducer can operate as both a sound source and sound pick-up. The sensitivity of the transducer falls off sharply for frequencies + or - 40 KHz. This can be seen by trying to talk into the pickup (lower than 40 KHz). Jingling keys have harmonics which extend as high as 40 KHz.

Note: Do not treat the transducers roughly. They are fragile. Use low settings for oscillator output, and high scope sensitivity. The transducer will be ruined if input power is > than 100 mw.



SOUND SPECTRUM/SOURCES. **B+45+15**

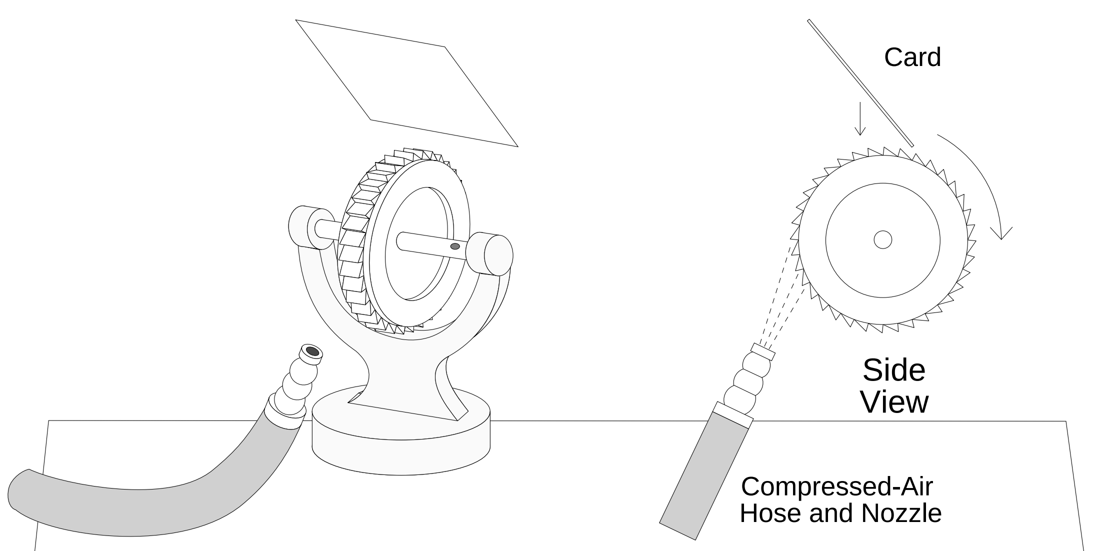
Bell ringing in a slowly evacuated (or aerated) chamber.



Both the Bell Jar and the vacuum flask apparatus have valves to either pump air out or let air in. Sound diminishes fairly rapidly as air is pumped out of either chamber.

SOUND SPECTRUM/SOURCES. **B+45+20**

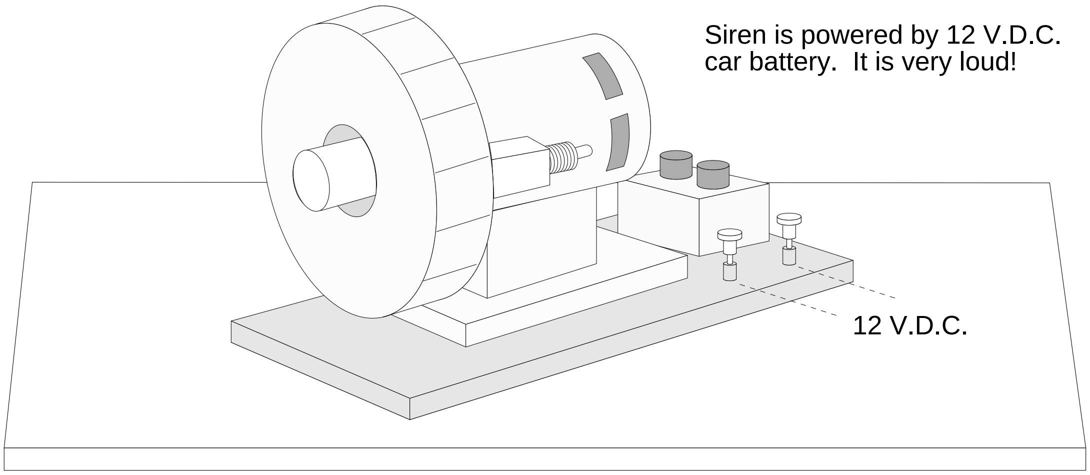
Savart's Wheel: Air or a card running over a Toothed Wheel generates sound.



Savart's wheel is much like a gyro with teeth around the rim. It can be set to spinning with a string,- and the card is pressed against the metal teeth to make a sound of a certain frequency. OR,- an air hose can spin the wheel by blowing against the teeth, generating a sound whose frequency depends on the force of the air.

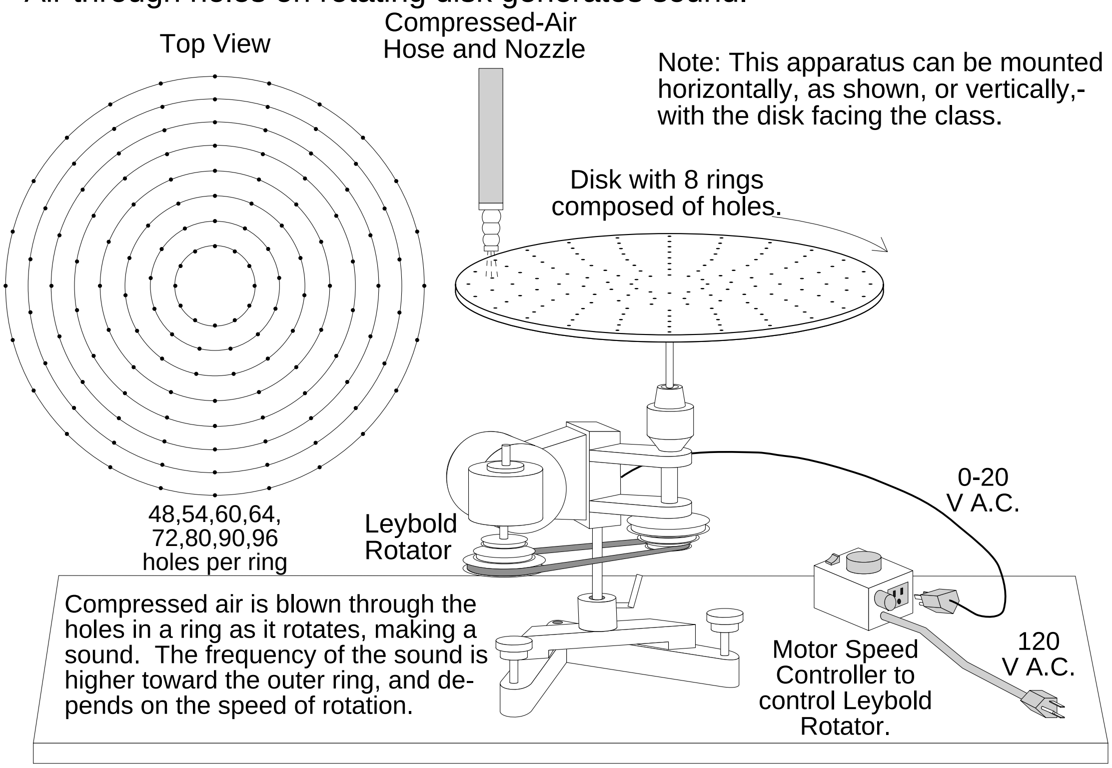
SOUND SPECTRUM/SOURCES. B+45+25

Siren.



SOUND SPECTRUM/SOURCES. B+45+30

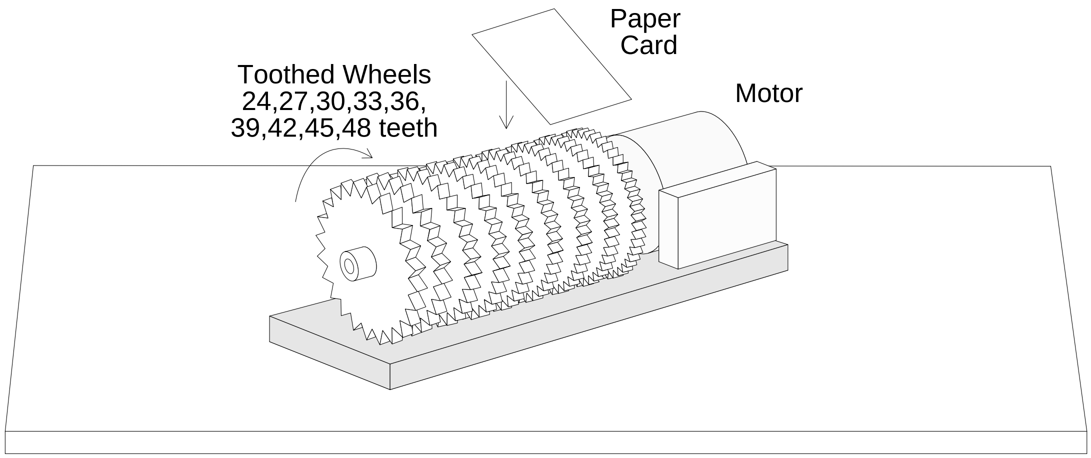
Air through holes on rotating disk generates sound.



SOUND SPECTRUM/SOURCES. B+45+35

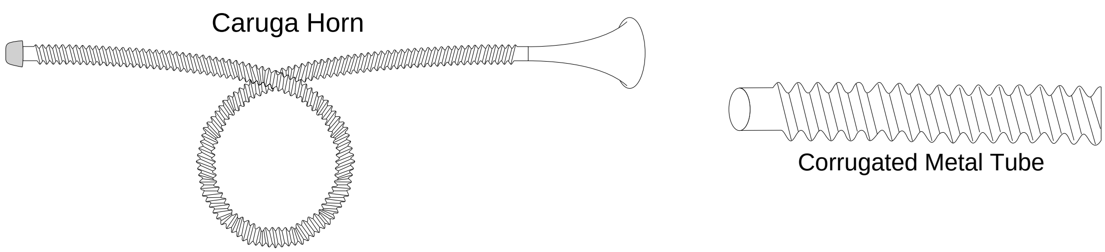
Card pushed against rotating toothed wheels makes sounds.

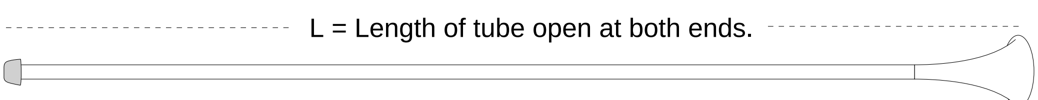
A paper card is pressed against one of the toothed wheels, generating a sound. The frequency of the sound increases with the number of teeth on a wheel, and the motor speed.



SOUND SPECTRUM/SOURCES. B+45+40

Caruga Horn: Blowing corrugated pipe emits various frequencies.



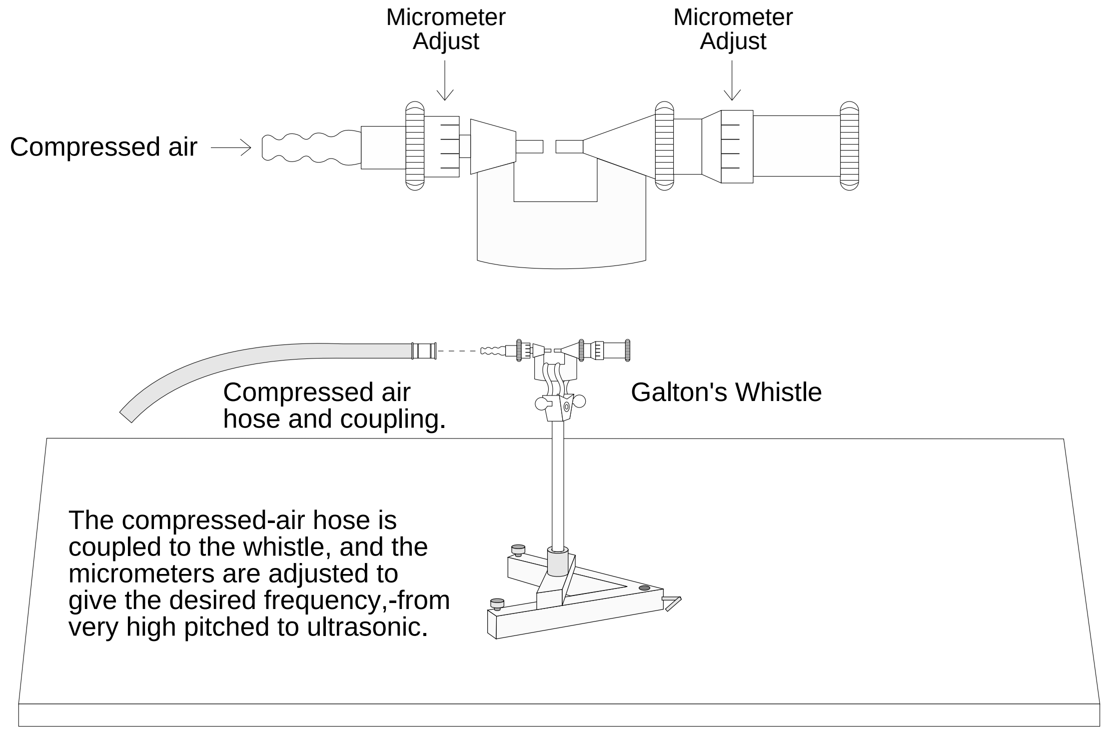


Caruga Horn unwrapped. (Corrugations not shown.)

For a tube open at both ends, $L = n\lambda/2$, where $n = 1,2,3...$, and λ is the wavelength.
The tube frequency $f = V/\lambda$, where V = velocity of sound in air (about 331 M/sec).
Thus, $f = nV/2L = n(V/2L) = nf_1$, where f_1 is the fundamental or first harmonic.
The first harmonic is f_1, the second harmonic is $2f_1$, the third harmonic is $3f_1$, etc.
The tube will resonate at any of the harmonics when excited with a harmonic frequency.
Air passing at a speed S over the corrugated bumps produces a sound of frequency
f = Bumps/Sec = (Bumps/M)(M/Sec) = (Bumps/M)S . S is determined by how hard you blow through the tube. If you blow at a speed that produces a non-harmonic frequency, then no sound will be heard. If you blow at a speed that produces a harmonic frequency, then the tube will resonate loudly at some multiple of the fundamental frequency.

SOUND SPECTRUM/SOURCES. B+45+45

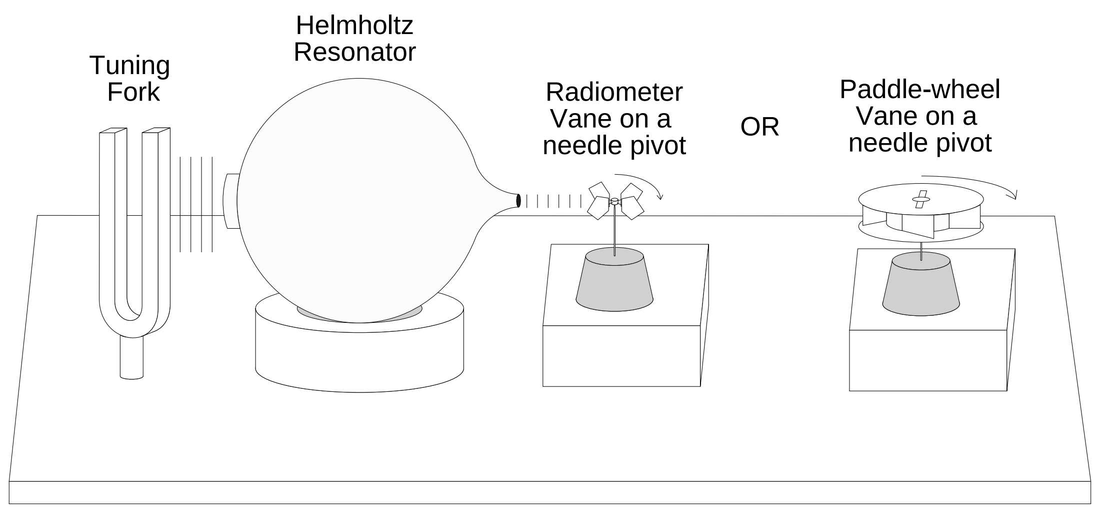
Galton's Whistle: from audible to ultrasonic frequencies.



SOUND SPECTRUM/SOURCES. B+45+50

Helmholtz Resonators drive vanes.

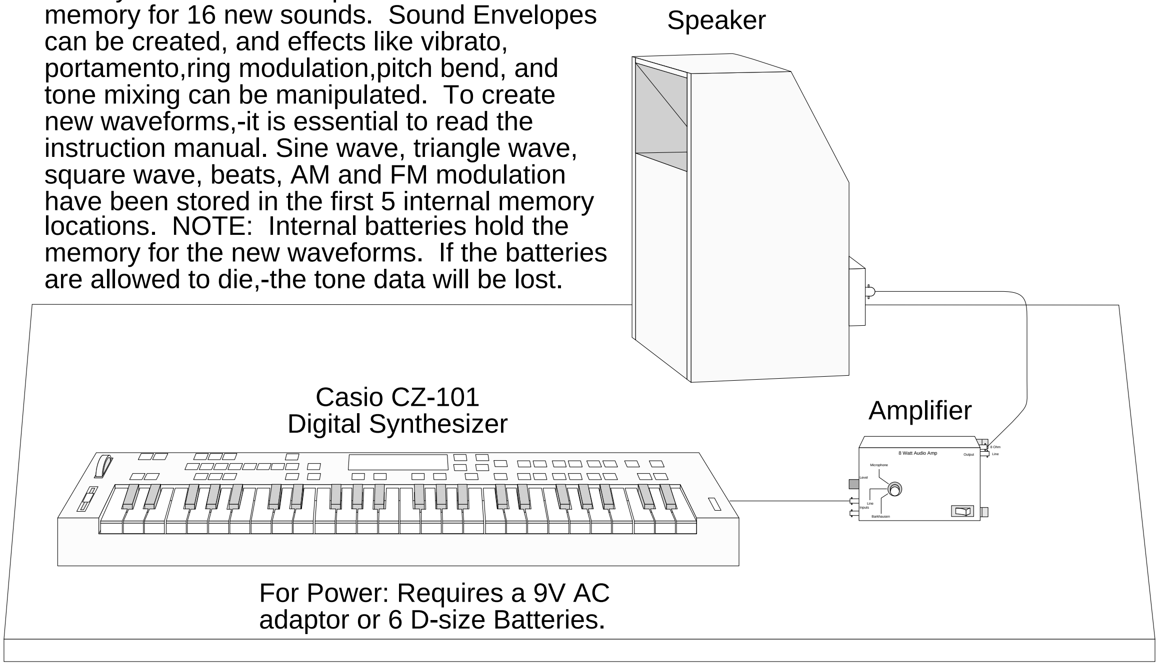
A tuning fork is held by hand in front of a Helmholtz Resonator. The resonator is basically a hollow metal sphere with a wide opening at one end, and a narrow opening at the other end. Pressure waves from the vibrating fork are focused onto the vanes mounted on a needle pivot,-causing the vanes to rotate.
Note: There are a number of different size resonators, each tuned to a different frequency tuning fork.



SOUND SPECTRUM/SOURCES. **B+45+55**

Casio CZ-101 Digital Synthesizer.

The Synthesizer has 16 preset instruments and memory for 16 new sounds. Sound Envelopes can be created, and effects like vibrato, portamento,ring modulation,pitch bend, and tone mixing can be manipulated. To create new waveforms,-it is essential to read the instruction manual. Sine wave, triangle wave, square wave, beats, AM and FM modulation have been stored in the first 5 internal memory locations. NOTE: Internal batteries hold the memory for the new waveforms. If the batteries are allowed to die,-the tone data will be lost.

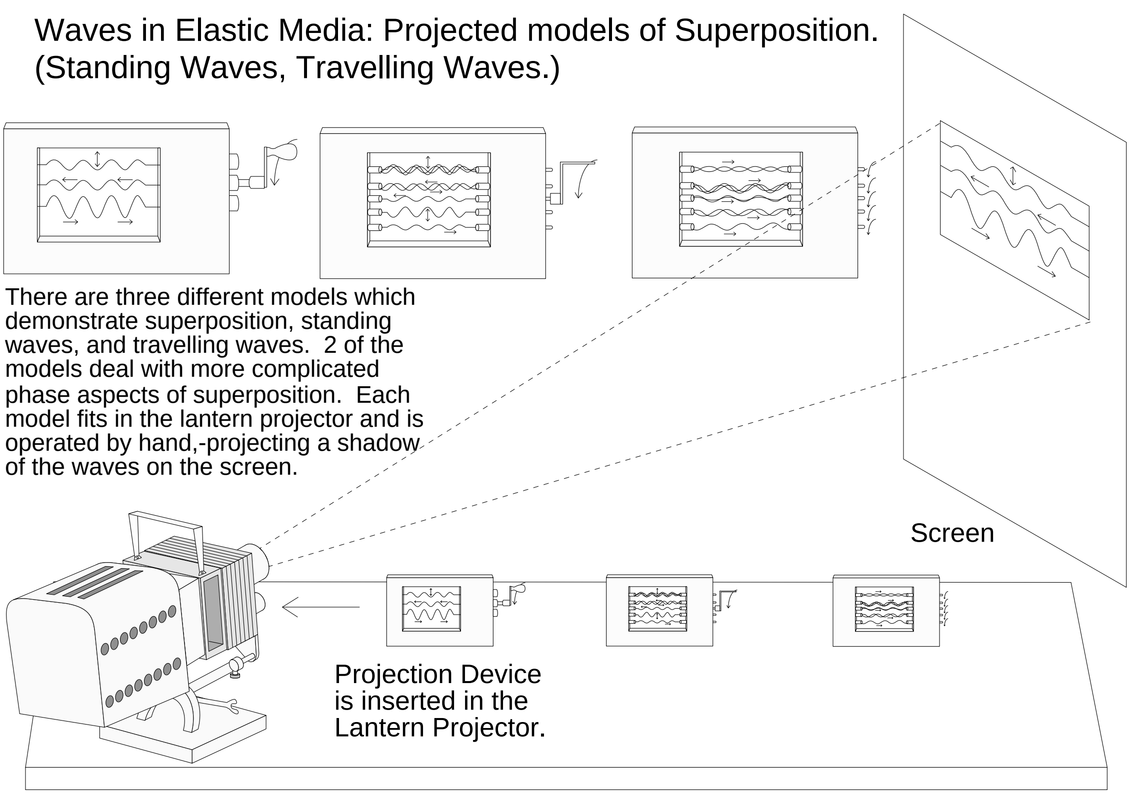


OPTIONAL: An Oscilloscope, and T.V. camera to send video images of the synthesizer waveforms to classroom t.v. monitors.

STANDING WAVES/RESONANCE. **B+50+0**

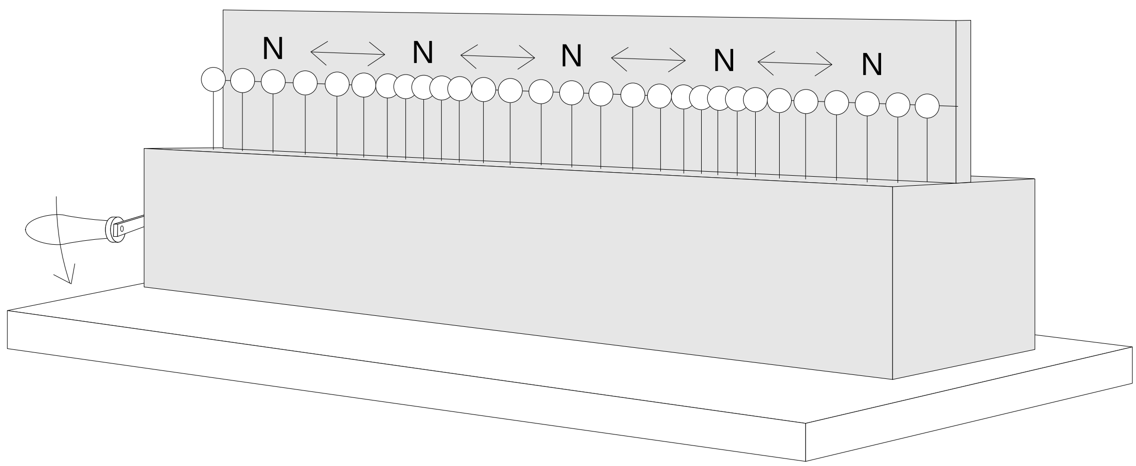
Waves in Elastic Media: Projected models of Superposition.
(Standing Waves, Travelling Waves.)

There are three different models which demonstrate superposition, standing waves, and travelling waves. 2 of the models deal with more complicated phase aspects of superposition. Each model fits in the lantern projector and is operated by hand,-projecting a shadow of the waves on the screen.



STANDING WAVES/RESONANCE. **B+50+5**

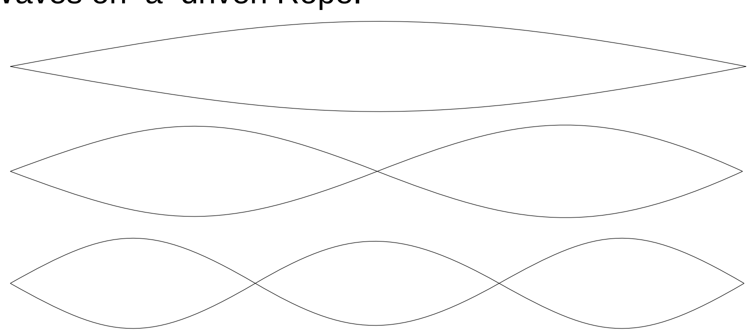
Machine Model for Longitudinal Standing Waves.



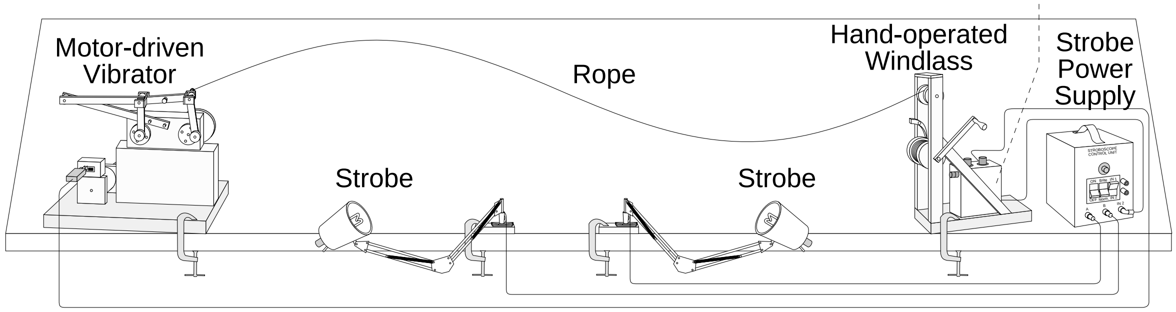
Cranking the handle creates a longitudinal standing wave. N marks each node. Each node is stationary. Consecutive nodes are, alternately, at regions of compression or rarifaction. As the handle turns, a compressed region becomes rarified, and vice versus.

STANDING WAVES/RESONANCE. **B+50+10**

Standing Waves on a driven Rope.



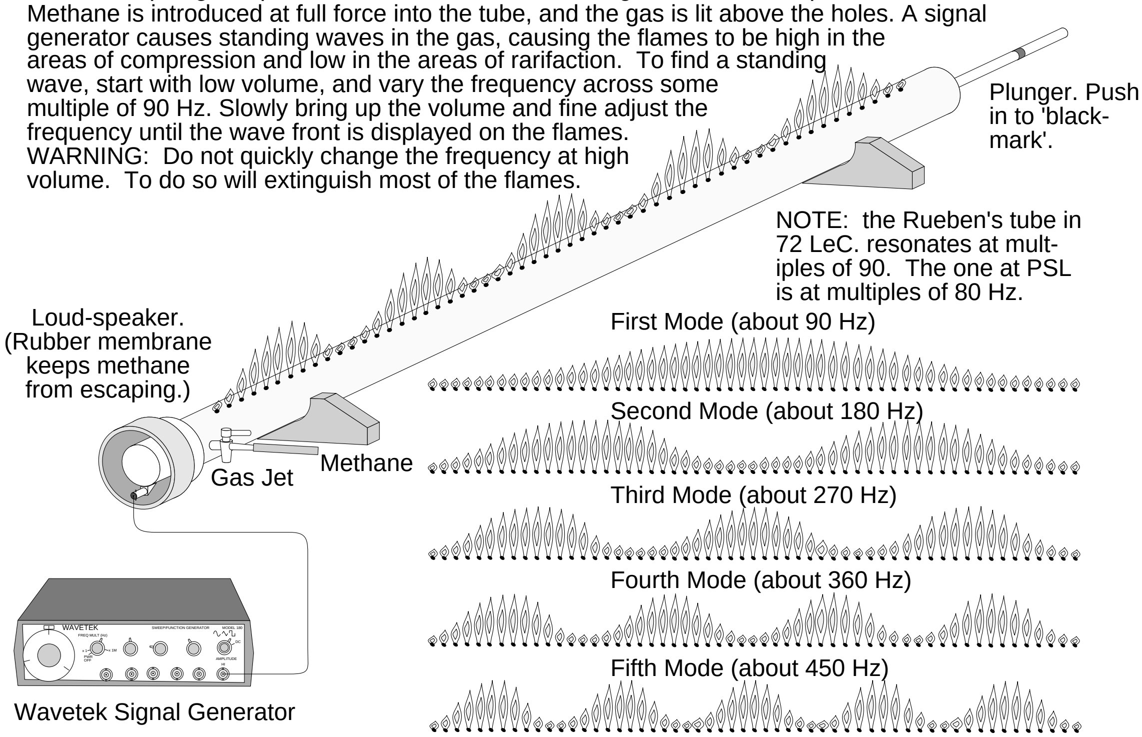
The rope tension is adjusted by hand, using the windlass crank. Motor speed and strobe rate are adjusted to freeze the rope in the first mode, second mode, third mode, etc.



STANDING WAVES/RESONANCE. B+50+15

Standing Longitudinal Waves in a gas: Reuben's Tube.

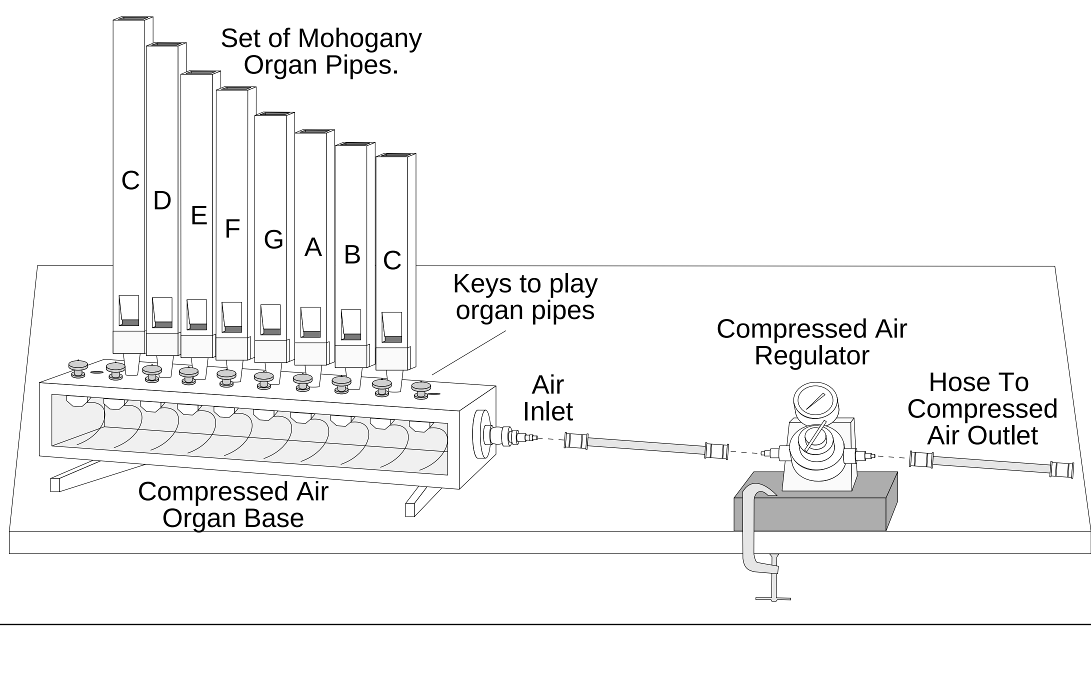
A 12' steel tube has holes along the top. A speaker is at one end, and a 'tuning' plunger is at the other. The plunger is pushed in to the black mark, tuning the tube to multiples of about 90 Hz. Methane is introduced at full force into the tube, and the gas is lit above the holes. A signal generator causes standing waves in the gas, causing the flames to be high in the areas of compression and low in the areas of rarifaction. To find a standing wave, start with low volume, and vary the frequency across some multiple of 90 Hz. Slowly bring up the volume and fine adjust the frequency until the wave front is displayed on the flames. WARNING: Do not quickly change the frequency at high volume. To do so will extinguish most of the flames.



STANDING WAVES/RESONANCE. B+50+20

Vibrating Air Columns: Organ Pipes.

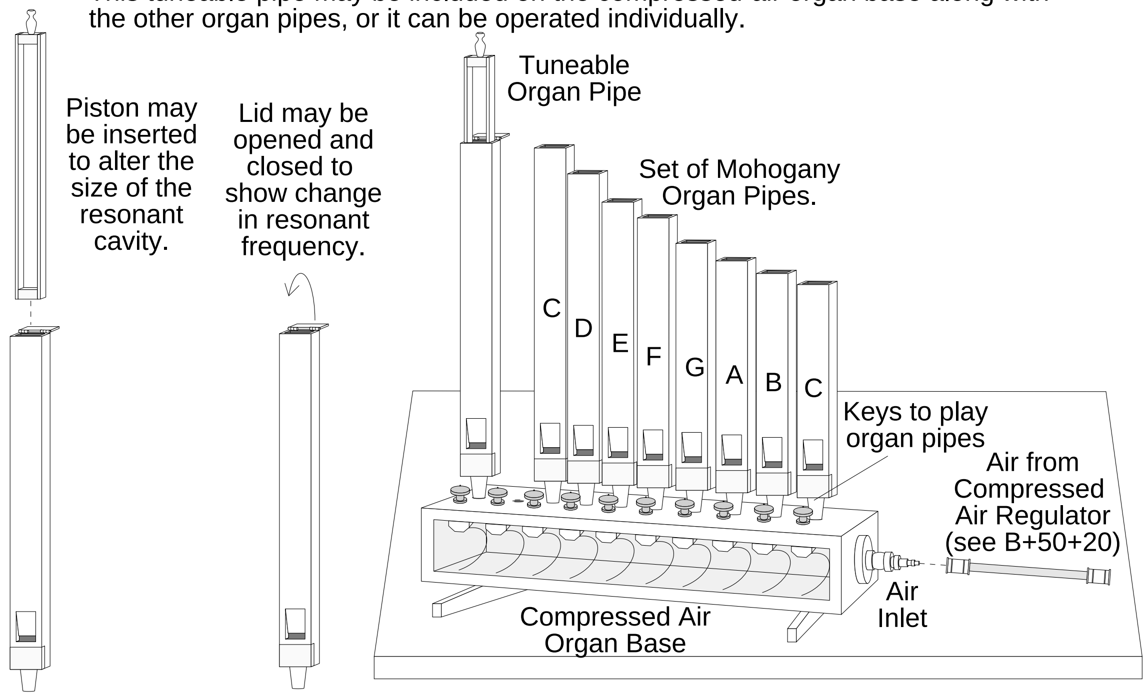
These organ pipes can be played individually. They reproduce one octave of the Major scale. The relative lengths of the pipes are in exact proportion to the frequency ratios of the notes.



STANDING WAVES/RESONANCE. **B+50+25**

Vibrating Air Columns: A tuneable Organ Pipe.

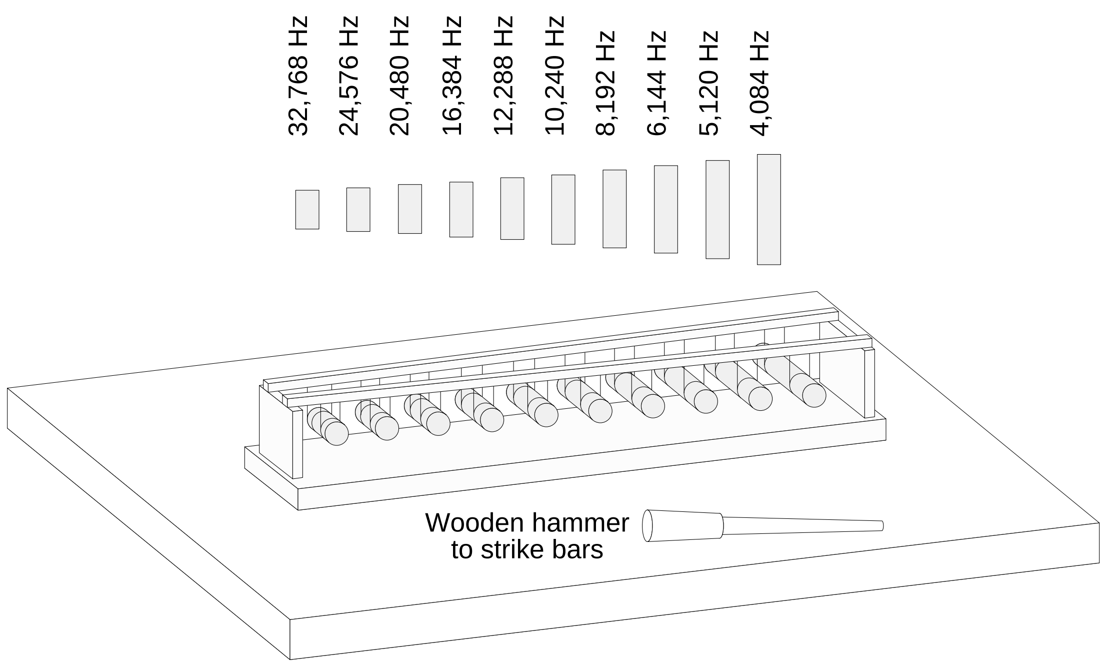
A Piston may be inserted in an organ pipe to alter the size of the resonant cavity.
Or, the lid may be closed to show the change in the resonant frequency.
This tuneable pipe may be included on the compressed-air organ base along with the other organ pipes, or it can be operated individually.



STANDING WAVES/RESONANCE. **B+50+30**

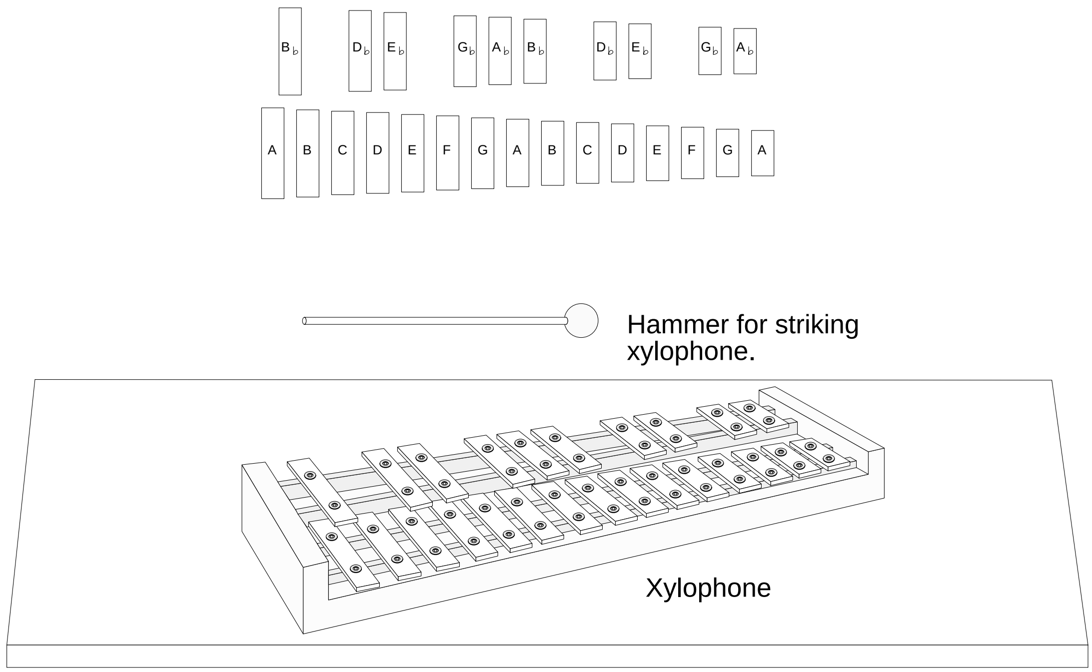
Metal cylinders struck with a wooden hammer.

This is a set of 10 solid metal cylinders suspended on strings to resonate from 4084 Hz to 32,768 Hz. A small wooden hammer is used to strike the bars.



STANDING WAVES/RESONANCE. B+50+35

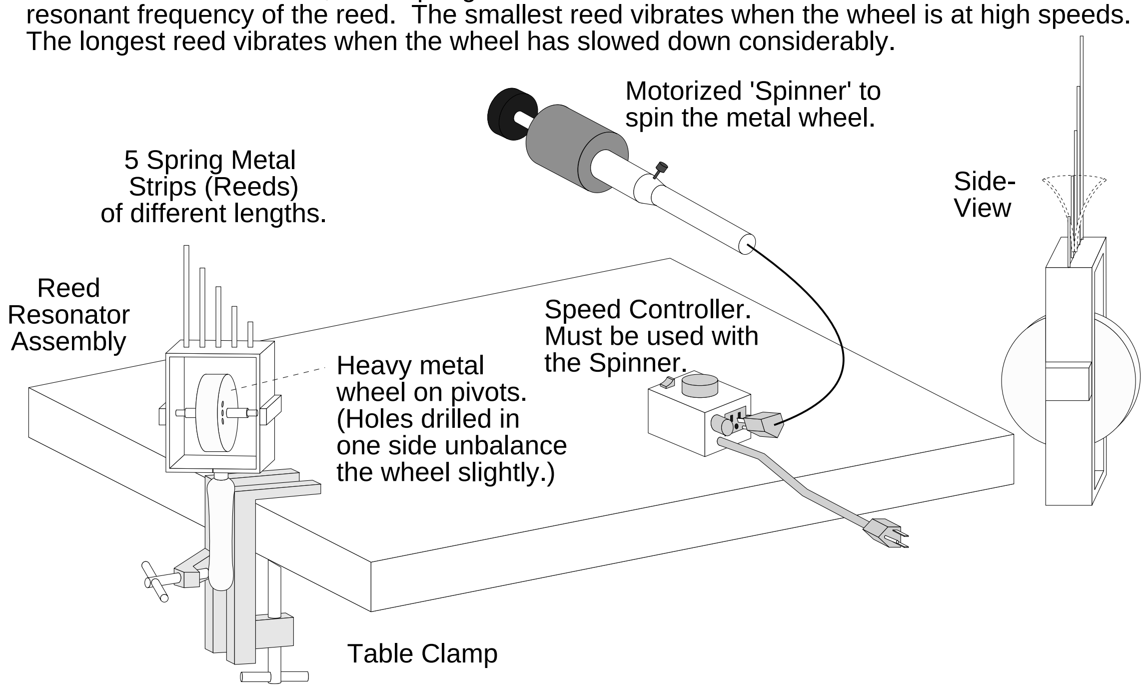
Xylophone: flat metal bars of different length struck with a hammer.



STANDING WAVES/RESONANCE. B+50+45

Steel Reed Resonator.

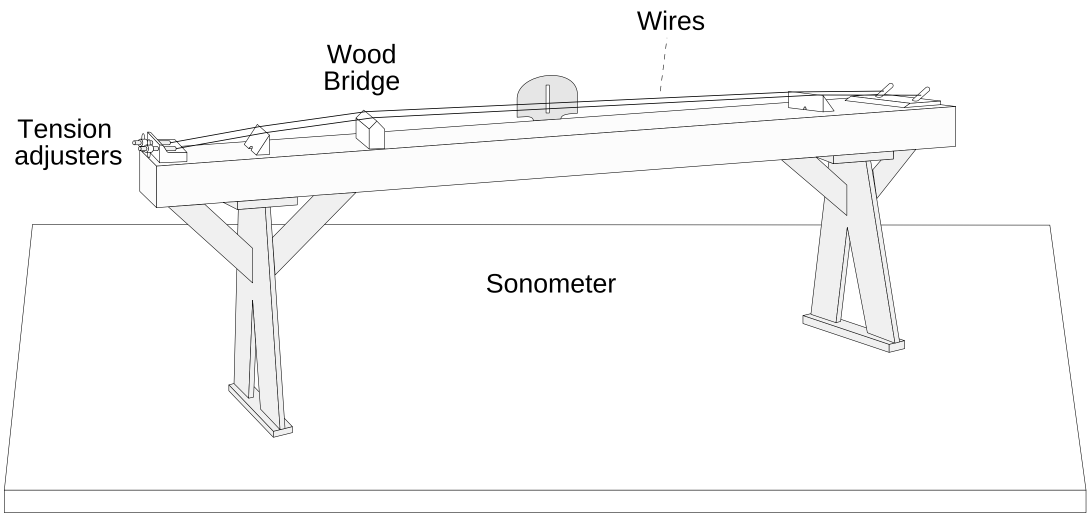
A heavy, metal,slightly unbalanced wheel (gyro) in the Resonator Assembly is set to spinning. As the wheel slows down, each spring steel reed will start to vibrate when the wheel hits the resonant frequency of the reed. The smallest reed vibrates when the wheel is at high speeds. The longest reed vibrates when the wheel has slowed down considerably.



STANDING WAVES/RESONANCE. **B+50+50**

Sonometer: Stretched piano wires on a sounding board.

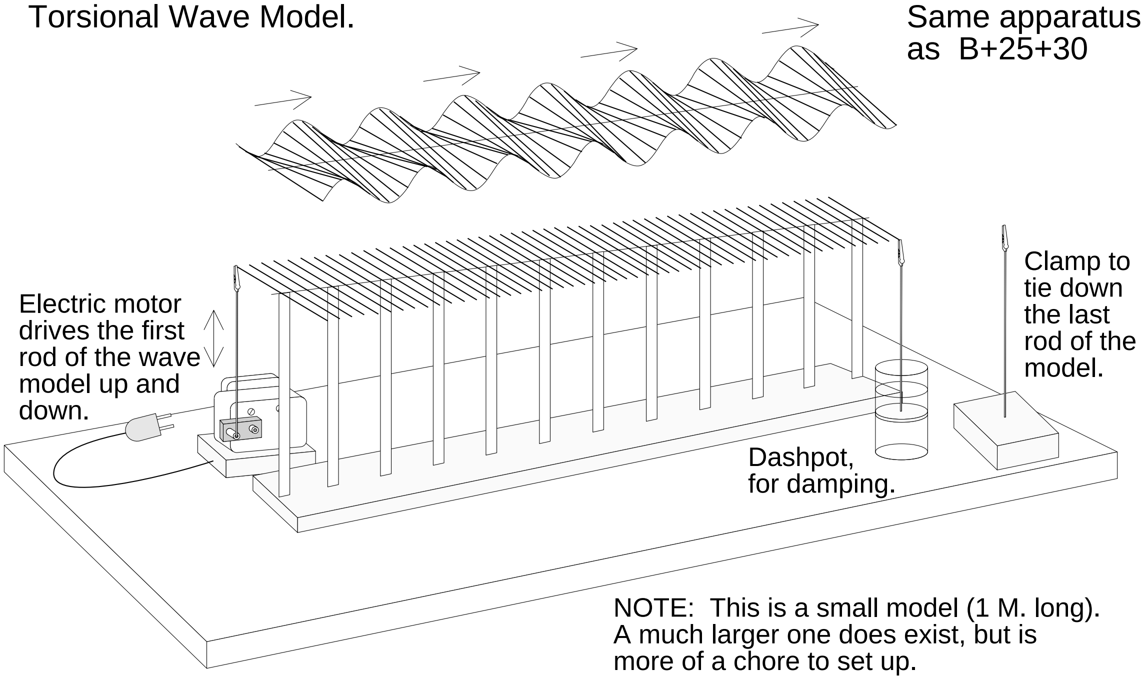
Two piano wire strings are stretched on a long sounding box. There is a tension-adjuster for each wire. A wood block (a bridge) with a sharp edge may be moved left or right. Each wire can be plucked to the left or the right of the wood bridge.



STANDING WAVES/RESONANCE. **B+50+55**

Torsional Wave Model.

Same apparatus as B+25+30



Light-weight rods are mounted ,in a parallel fashion, on a long piece of spring-steel wire. An electric motor (or hand) can be used to introduce a periodic oscillation to one rod to illustrate standing waves,resonance or travelling waves. The opposite end can be free or tied down,-or connected to a dash-pot assembly for damping,-or connected to another model of different dimensions.

VIBRATIONAL MODES. B+55+0

Film Loop: Vibrations of a Metal Plate Length (min.):3:45

Color: No Sound: No Note: This is also available on videotape.

In many finite physical systems, we can generate a phenomenon known as standing waves. A wave in a medium is usually reflected at the boundaries. Characteristic patterns will sometimes be formed, depending on the shape of the medium, the frequency of the wave, and the material. At certain points or lines in these patterns there are no vibrations, because all the partial waves passing through these points just manage to cancel each other out through superposition.

Standing wave patterns only occur for certain frequencies. The physical process selects a spectrum of frequencies from all the possible ones. Often there are an infinite number of such discrete frequencies. Sometimes there are simple mathematical relationships between the selected frequencies, but for other bodies the relationships are more complex. Several films in this series show vibrating systems with such patterns.

The physical system in this film is a square metal plate. The various vibrational modes are produced by a loudspeaker, as with the vibrating membrane in "Vibrations of a Drum". The metal plate is clamped at the center, so that point is always a node for each of the standing wave patterns. Because this is a metal plate, the vibrations are too slight in amplitude to be directly seen. The trick used to make the patterns visible is to sprinkle sand on the plate. This sand is jiggled away from the parts of the plates in rapid motion and tends to fall along the nodal lines. The beautiful patterns of sand are known as Chaladni figures which have often been admired by artists. Similar patterns are formed when a metal plate is excited by means of a violin bow, as seen at the end of the film.

Not all frequencies lead to stable patterns. As in the case of the drum, the harmonic frequencies for the metal plate obey complex mathematical relationships, rather than the simple arithmetic progression seen in a one-dimensional string. But as we scan the frequency spectrum, only certain sharp, well-defined frequencies produce these elegant patterns.

VIBRATIONAL MODES. B+55+1

Film Loop: Vibrations of a Drum Length (min.):3:25

Color: No Sound: No Note: This is also available on videotape.

In many finite physical systems, we can generate a phenomenon known as standing waves. A wave in a medium is reflected at the boundaries. Characteristic patterns will sometimes be formed, depending on the shape of the medium, the frequency of the wave and the material. At certain points or lines in these patterns there are no vibrations, because all the partial waves passing through these points just manage to cancel each other out, through superposition.

Standing wave patterns only occur for certain frequencies. The physical process selects a spectrum of frequencies from all the possible ones. Often there are an infinite number of such discrete frequencies. Sometimes there are simple mathematical relationships between the selected frequencies, but for other bodies the relationships are more complex. Several films in this series show vibrating systems with such patterns.

The standing wave patterns in this film are in a stretched, circular, rubber membrane driven by a loudspeaker. The loudspeaker is fed about 30 watts of power. The sound frequency can be changed electronically. The lines drawn on the membrane make it easier to see the patterns.

The rim of the drum can not move, so it must be in all cases a nodal circle, a circle which does not move as the waves bounce back and forth on the drum. By operating the camera at a frequency only slightly different from the resonant frequency, we get a stroboscopic effect enabling us to see the rapid vibrations as if they were in slow-motion.

In the first part of the film, the loudspeaker is directly under the membrane, and the vibratory patterns are symmetrical. In the fundamental harmonic, the membrane rises and falls as a whole. At a higher frequency a second circular node shows up between the center and the rim.

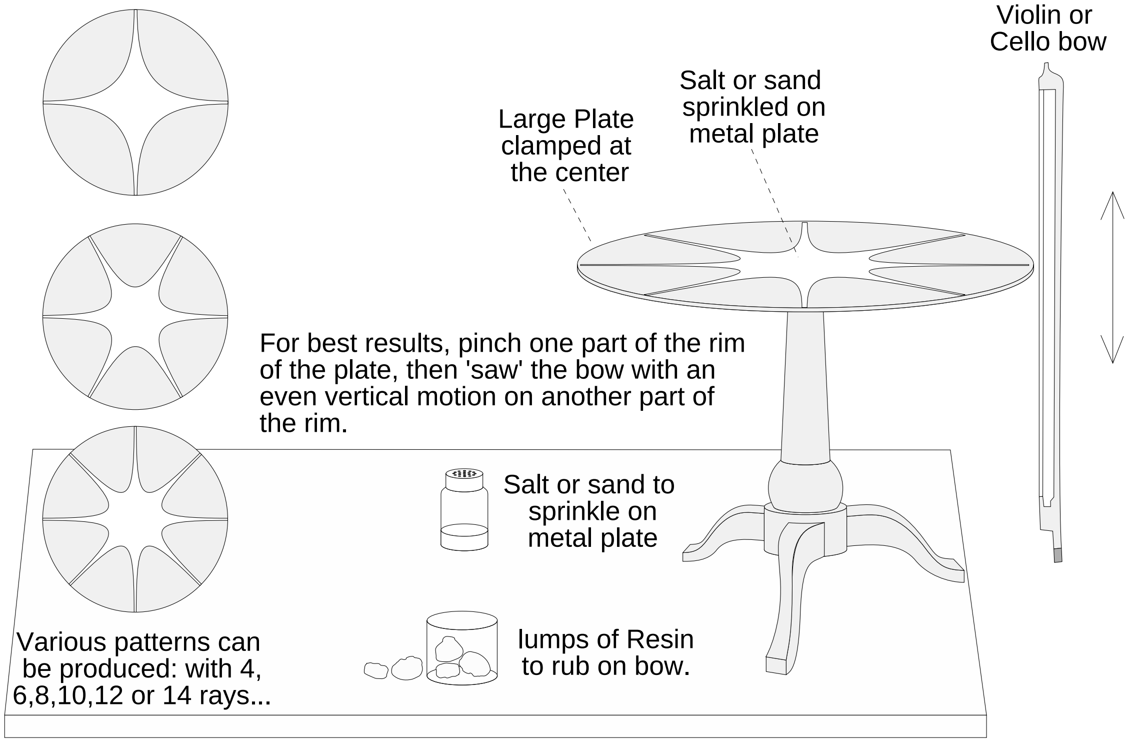
In the second part of the film, the speaker is placed to one side, so that a different set of modes, asymmetrical modes, are generated in the membrane. There will be an anti-symmetrical mode where there is a node along the diameter, with a hill on one side and a valley on the other.

Various symmetric and anti-symmetric vibration modes are shown. Describe each mode, identifying the nodal lines and circles.

In contrast to the one-dimensional hose in "Vibrations of a Rubber Hose" there is no simple relationship between resonant frequencies for this system. The frequencies are not integral multiples of any basic frequency. The relationship between values in the frequency spectrum is more complex than the values for the hose.

VIBRATIONAL MODES. B+55+5

Chladni's Figures : Vibrational modes of a metal plate.

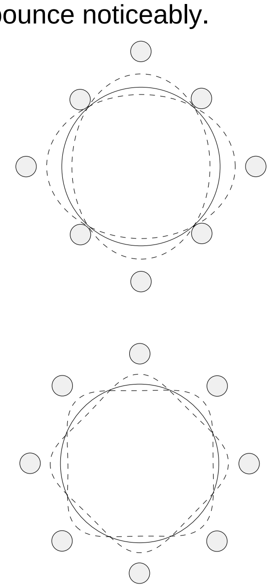


For best results, pinch one part of the rim of the plate, then 'saw' the bow with an even vertical motion on another part of the rim.

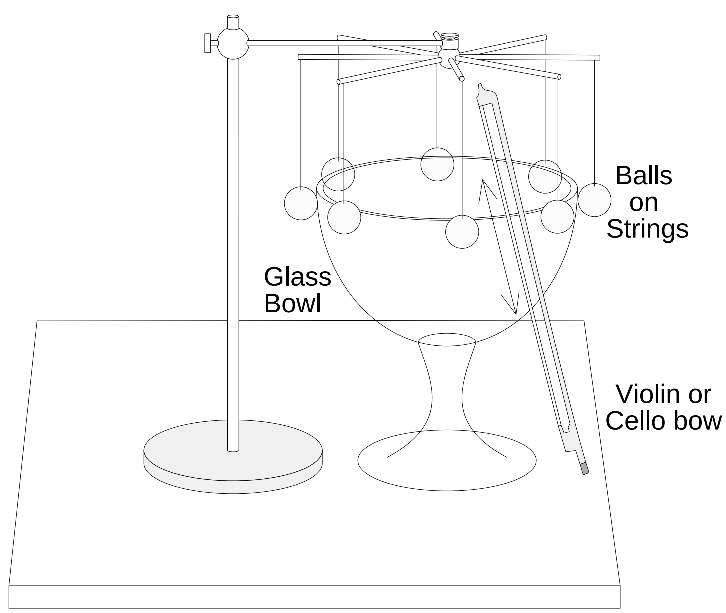
VIBRATIONAL MODES. B+55+10

Vibrational modes of a thin glass bowl.

The apparatus consists of a large glass bowl 12" in diameter, surrounded by a ring of balls near the lip. The edge of the bowl is caused to vibrate in standing wave patterns, by use of a violin or cello bow. The harmonic can be selected by defining nodes on the lip with mild pressure from a finger on the hand not using the bow. Balls residing over nodes will not move while the bowl is being stimulated; balls located over antinodes will vibrate and bounce noticeably.

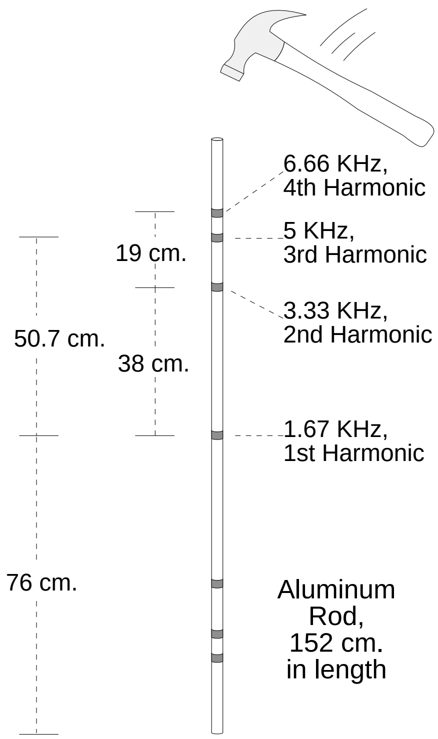


Different Vibrational Modes...



VIBRATIONAL MODES. B+55+15

Young's Modulus: Aluminum rod, held at a node and struck on the end, rings.



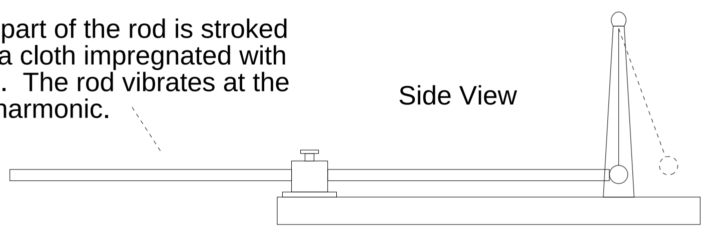
The aluminum rod is held vertically at one of the nodal points (marked in black), and the end of the rod is struck by the hammer. The rod will loudly resonate at one of the harmonic frequencies for a long time.

Note: There are two rods of different lengths. The rod of 152 cm. in length has a first harmonic of 1.67 KHz. The second rod of 121 cm. in length has a first harmonic of 2 KHz.

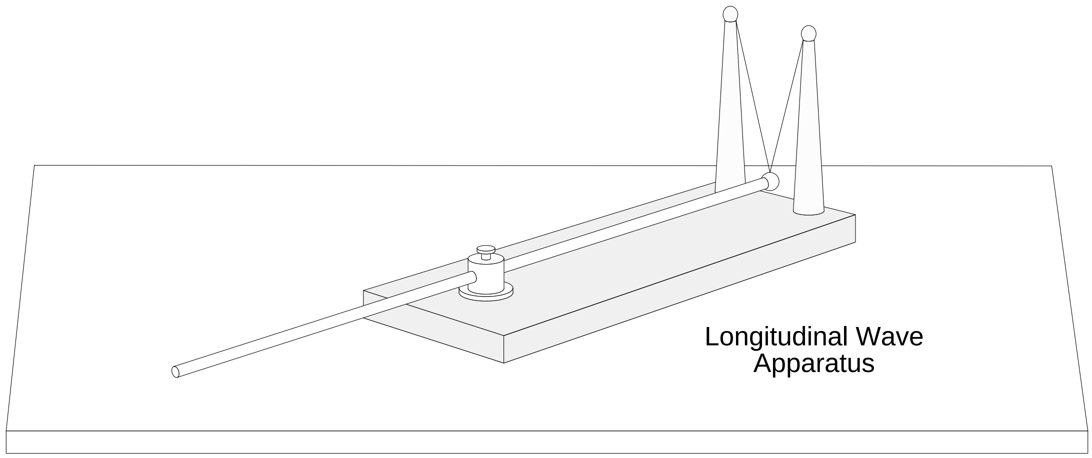
VIBRATIONAL MODES. B+55+20

Longitudinal Waves in a Rod: ball bounces off end of stroked rod.

This part of the rod is stroked with a cloth impregnated with resin. The rod vibrates at the first harmonic.

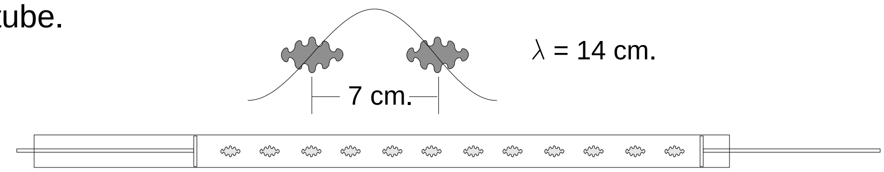


Ball bounces off end of rod and swings up.

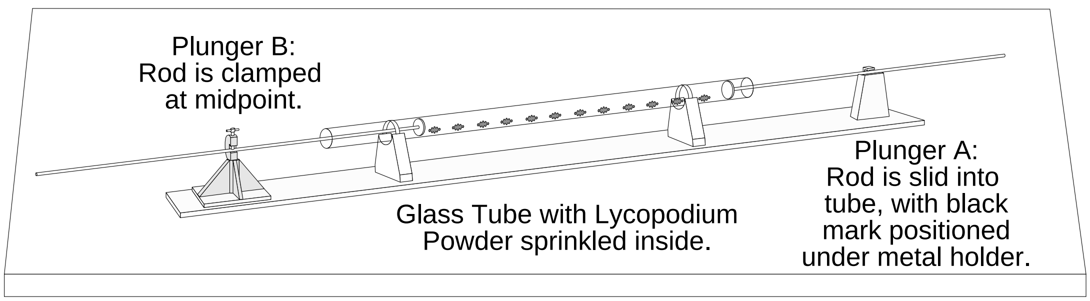


VIBRATIONAL MODES. B+55+25

Kundt's Tube: resonant frequency of a stroked rod causes nodal patterns in dust in a tube.



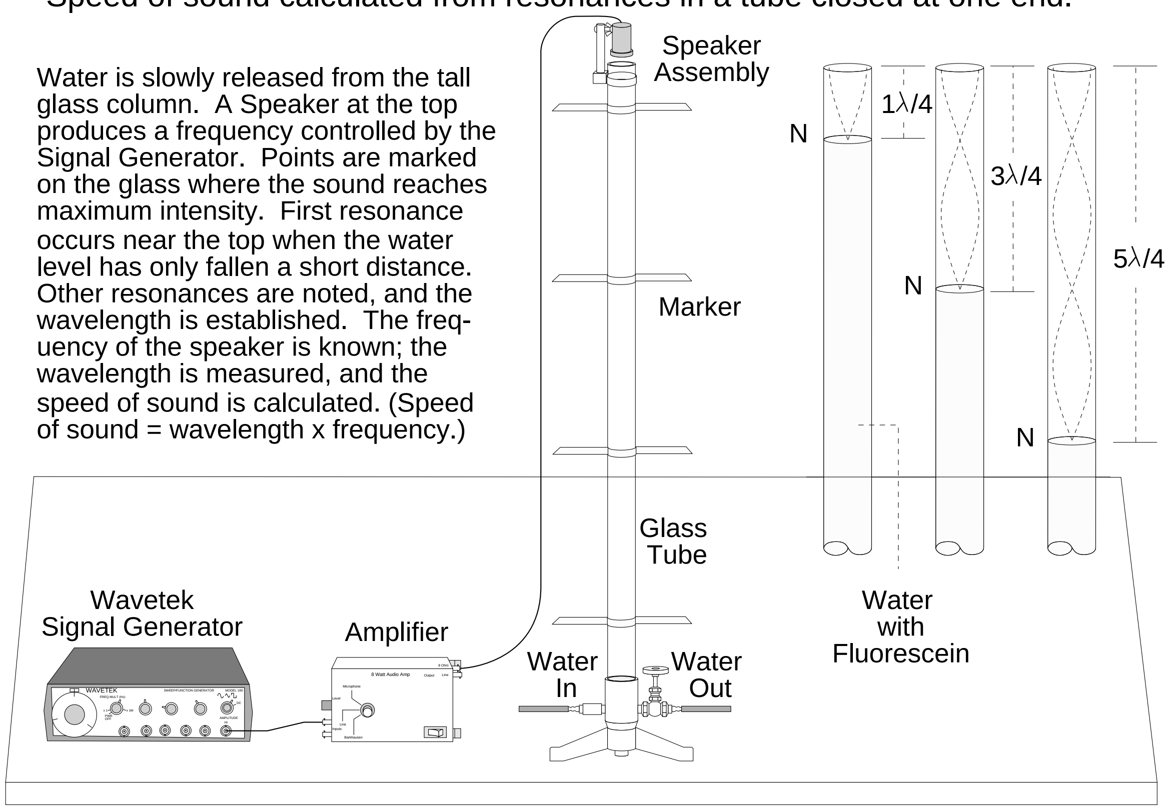
The apparatus is clamped to a table. Plunger A is adjusted. The rod of Plunger B is stroked with a cloth impregnated with resin, causing the rod to resonate loudly (at first harmonic = 2,470 Hz). This excites powder in the glass tube to form patterns in the nodal regions. The frequency f of the resonating rod B can be determined,knowing the distance between the nodes. [f = (speed of sound divided by λ) = (344m/sec)/.14m = 2457 Hz.]



SPEED OF SOUND. B+60+0

Speed of sound calculated from resonances in a tube closed at one end.

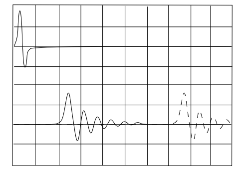
Water is slowly released from the tall glass column. A Speaker at the top produces a frequency controlled by the Signal Generator. Points are marked on the glass where the sound reaches maximum intensity. First resonance occurs near the top when the water level has fallen only a short distance. Other resonances are noted, and the wavelength is established. The frequency of the speaker is known; the wavelength is measured, and the speed of sound is calculated. (Speed of sound = wavelength x frequency.)

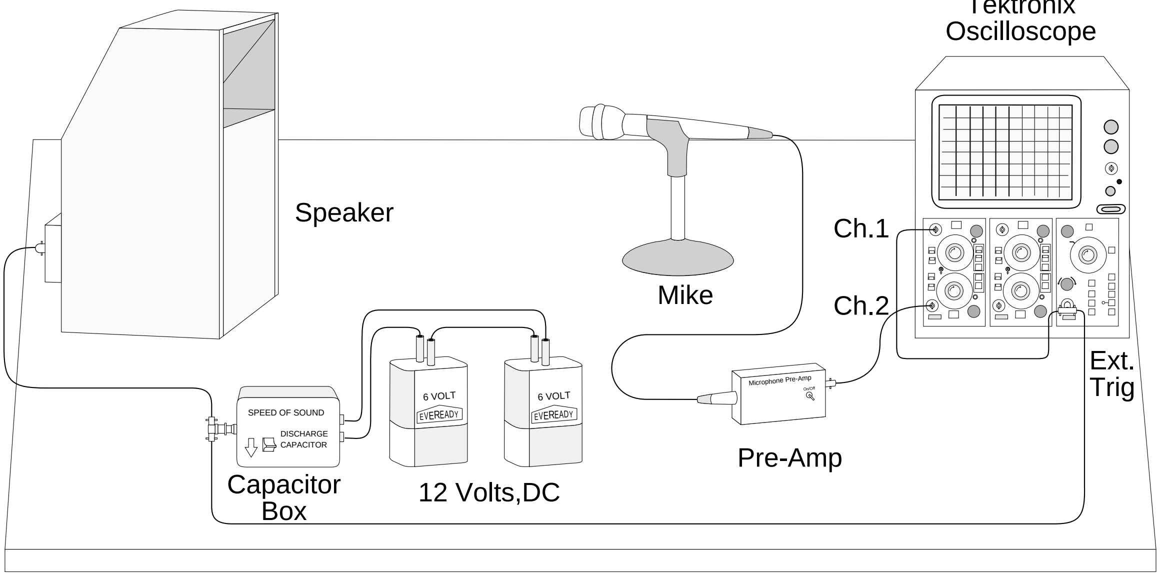


SPEED OF SOUND. B+60+5

Measurement of speed of sound with mike,speaker & oscilloscope.

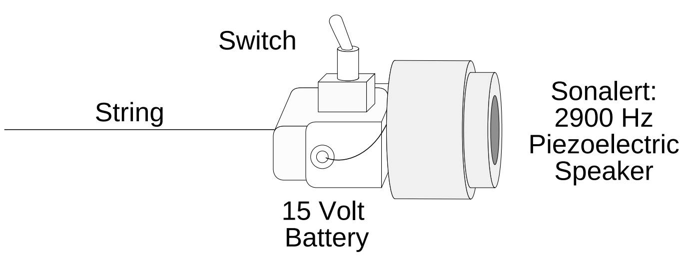
Pressing the switch on the capacitor box discharges the capacitor through the speaker,-producing an audible click. The discharge also triggers a single sweep of the oscilloscope, and the capacitor discharge is displayed on channel 1. At some later time t the click reaches the mike and is displayed on channel 2. The mike can be placed at different distances from the speaker, and the corresponding click waveforms can all be shown, using the storage function of the scope. The speed of sound is the distance between 2 mike positions divided by the difference between corresponding mike click-waveform times.





DOPPLER EFFECT. B+65+0

Sound source is swung on a string,-causing audible Doppler effect.



As the Sonalert swings toward you, the pitch increases slightly. As it swings away from you, the pitch decreases slightly. If swung at a high speed, the net effect is a sort of warble.

SHOCK WAVES B+65+5

Film Loop: Formation of Shock Waves Length (min.):3:45

Color: No Sound: No Note: This is also available on videotape.

A pulsed air jet producing a periodic circular wave first moves over the water surface at about 1/3 (and then 2/3) of the wave velocity; the wave fronts ahead of the source get closer together. When the source velocity exceeds the wave velocity (by about 5%) a shock wave builds up and moves along with the source. When the ratio of source to wave velocity is about 1.6 the cone of the shock wave is quite sharp. At one point the motion is frozen and animation is superposed to show the relationship of the shock wave angle to the wave and source velocities.

APPARATUS. Same as for Film-Loop 80-237.

NOTES. It took only 2.5 sec for the source to move across the tank at 1.6 times the wave velocity. In order to prevent stoboscopic effects and to be able to observe the effect for a reasonable time the sequence was photographed with a high speed camera. The film is designed to be screened at 16 frames per second (silent speed); the projected phenomena are slowed down by about a factor of 6. The ratio of source to wave velocity is usually called the Mach number. For Mach numbers greater than 1 the reciprocal of that number is equal to the sine of the half angle for the shock cone.

DATA AND DISCUSSION. In the sequence where we first see the shock wave (about Mach 1.05), the measured half angle of the shock cone is 73°. In the second sequence (about Mach 1.6) the measured half angle is about 40°; see Fig. 1. At Mach 1.6 we can see a circular concave wave to the rear of the source and moving in the same direction; this is the first circular wave formed as the source originally starts to move across one edge of the tank. What would you observe from the following vantage points: (a) outside the Mach cone, (b) inside the cone, (c) anywhere in the cone-shaped shock itself?

DOPPLER EFFECT. B+65+10

Film Loop: The Doppler Effect Length (min.):3:45

Color: No Sound: No Note: This is also available on videotape.

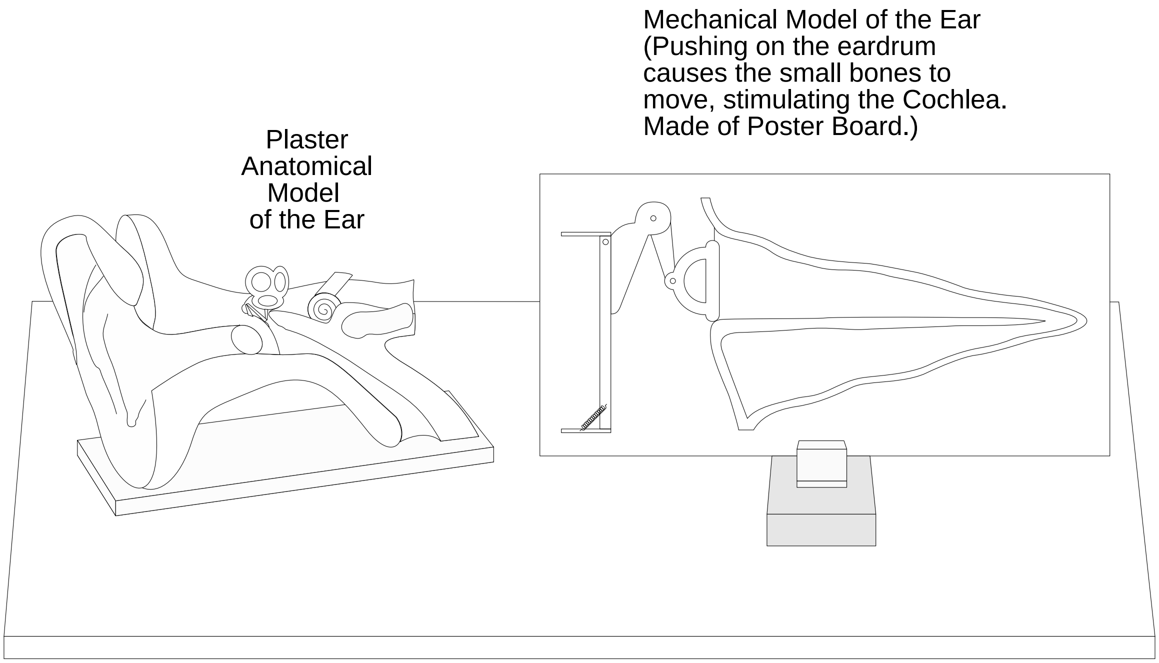
A pulsed air jet producing a periodic circular wave first moves over the water surface at about 1/3 of the wave velocity. The Doppler effect is clearly seen . At one point the motion is frozen on the screen to permit close examination of the wavelength differences. The source is also shown moving at twice the previous velocity.

APPARATUS. The water depth was not critical. The wave generator was a small drum hit by a vibrating clapper mounted on a cart which moved uniformly along the edge of the tank. A narrow tube from the drum protruded out over the tank and directed puffs of air onto the water surface.

NOTES. It took only 10 sec for the source to move across the tank at 1/3 times the wave velocity. In order to prevent stoboscopic effects and to be able to observe the effect for a reasonable time the sequence was photographed with a high speed camera. The film is designed to be screened at 16 frames per second (silent speed); the projected phenomena are slowed down by about a factor of 6. The magnitude of the Doppler effect shown here, with a ratio of source to wave velocity of about 1/3 to 2/3, is large compared to what we normally hear or record. The ratio is then usually 1/10 or 1/20; e.g. when we hear the change of pitch of a car horn or a train whistle as it moves past us at 30 to 60 mph. When the ratio of source to wave velocity is greater than 1, a shock wave occurs. (see Film 80-238) In Fig. 1 (not included here) a stationary observer in front of the source (on the right) sees the source approaching and measures a higher than normal frequency (pitch); an observer behind the source (on the left) sees the source receding and measures a lower than normal frequency.

MUSIC AND THE EAR. **B+70+0**

Ear Models: Anatomical Plaster Model, and Mechanical Poster Board Model.



MUSIC AND THE EAR. **B+70+5**

Film: The Piano.

Film Title: The Piano.
Level: Upper elementary-Adult.
Length: 27 minutes. Color and Sound.
Description: Everything you ever wanted to know about pianos. It shows how they are constructed; the physics of the struck piano wires; the acoustical properties, etc.