Oscillations and Waves

For the complete bibliography with references as well as an explanation of the classification scheme go to:

Demonstration Bibliography

The **demonstration name** listed in the bibliography is either the name listed on the reference or, if none is given, a simple descriptive name. In cases where there are several common names for a demonstration, the committee has chosen a preferred name.

The **description** is very brief. It is not intended to be a summary of the reference. One sentence is, in general, sufficient to describe the unique characteristics, if any, of an item. Each source has a unique numbering format. These unique formats are used identify references in the Bibliography.

The formats for the **reference** column and links to the sources are listed below:

Reference	Source
M-1	Sutton
Ma-1	Freier & Anderson
M-1d	Hilton
8-2.8	Meiners
M-108	Dick & Rae
1A 12.01	University of Minnesota Handbook
AJP 52(1),85	American Journal of Physics
TPT 15(5),300	The Physics Teacher
Disc 01-01	The Video Encyclopedia of Physics Demonstrations
PIRA 200	Physics Instructional Resource Association
PIRA 500	PIRA 500
PIRA 1000	PIRA 1000

Each demonstration is listed in only one location, even if it is commonly used to illustrate several concepts.

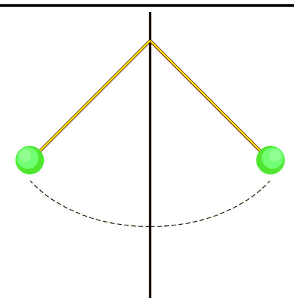
10/2/2023

Oscillations and Waves

OSCILLATIONS AND WAVES	3A10.10	OSCILLATIONS

Pendula

Simple Pendulum



The length of the pendulum is adjustable. A timer can be used to measure the period. One can also use Science Workshop and a Motion Detector.

Location: Eb1

OSCILLATIONS AND WAVES	3A10.14	OSCILLATIONS
Pendula		

4:1 Pendula

	4:1 Pendula have a 2:1 period. Release the two pendulum bobs at the same time and they will return to the release point together every other oscillation.

Location: Eb1

OSCILLATIONS AND WAVES	3A10.30	OSCILLATIONS
Pendula		

Torsion Pendulum

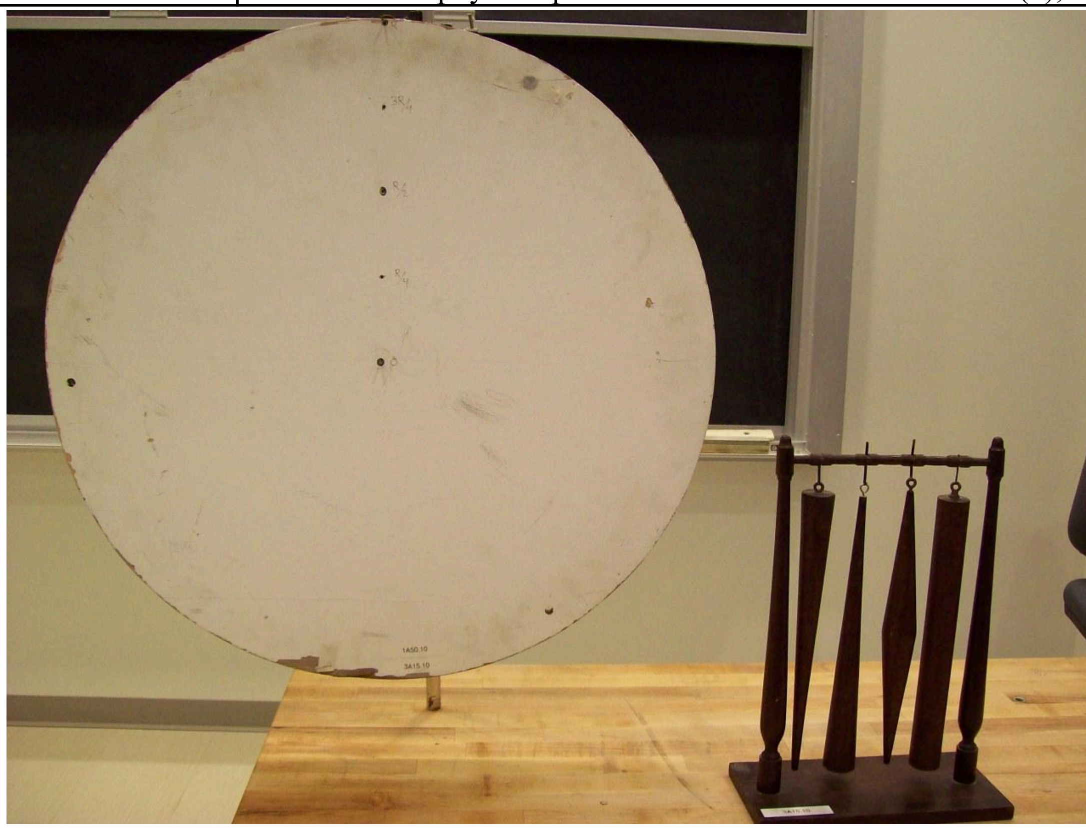
	The moment of inertia of the pendulum is adjustable. A timer can be used to measure the period. The torsion constant of the wire is 5.3 x 10^{-3} n•m/rad. The rotational inertia of the bar alone is 7.6 x 10^{-4} kg•m^2. Each of the masses is 0.23 kg. The rotational inertia of the bar with the 4 masses is 6.14 x 10^{-3} kg•m^2.

Location: Eb1

OSCILLATIONS AND WAVES	3A15.10	OSCILLATIONS
Physical Pendulum		

Physical Pendulum Set

	The large disc has support holes drilled at R, 3/4R, 1/2R and 1/4R from the center. The physical pendulum set is described in AJP 48(6), 487.

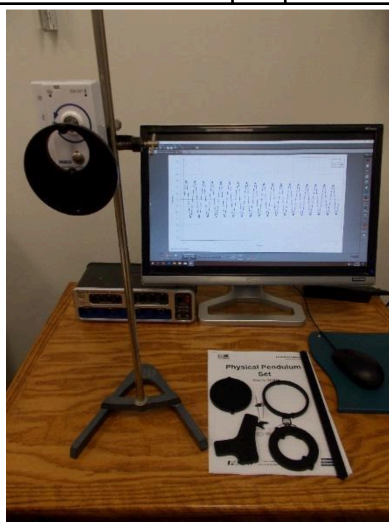


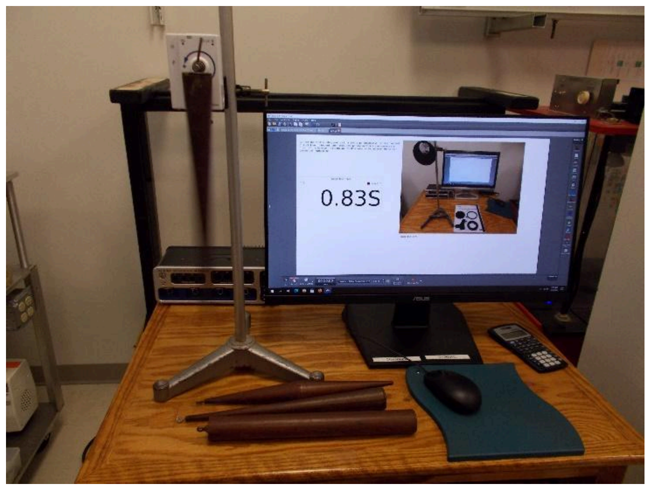
Location: Eb7, AaT

OSCILLATIONS AND WAVES	3A15.20	OSCILLATIONS
Physical Pendulum		

Physical Pendulum

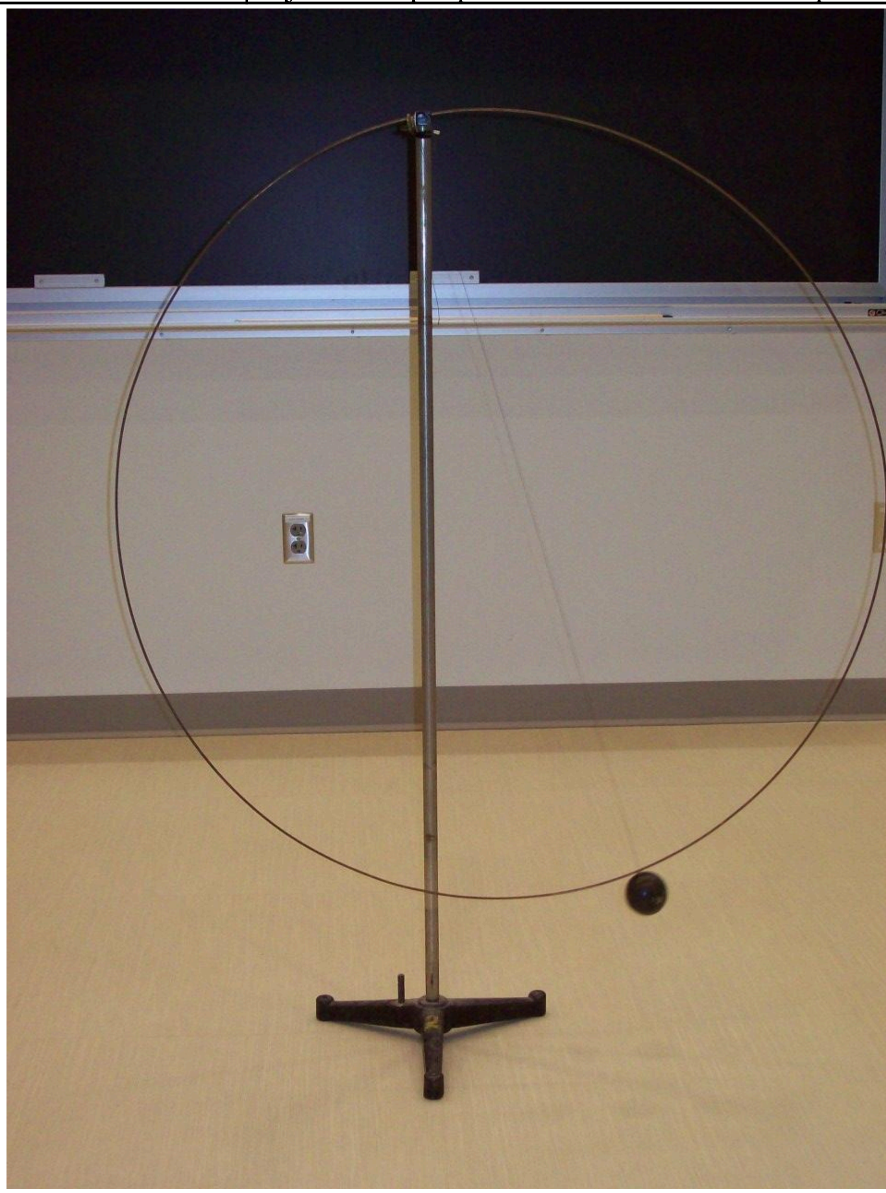
	Various physical pendula can be mounted to a wireless rotary motion sensor and their motions plotted and period displayed. Use the Capstone software with the file Physical Pendulum.cap. Make sure the Bluetooth connection to the sensor is made, then click on the record button, rotate the pendulum clockwise and release.





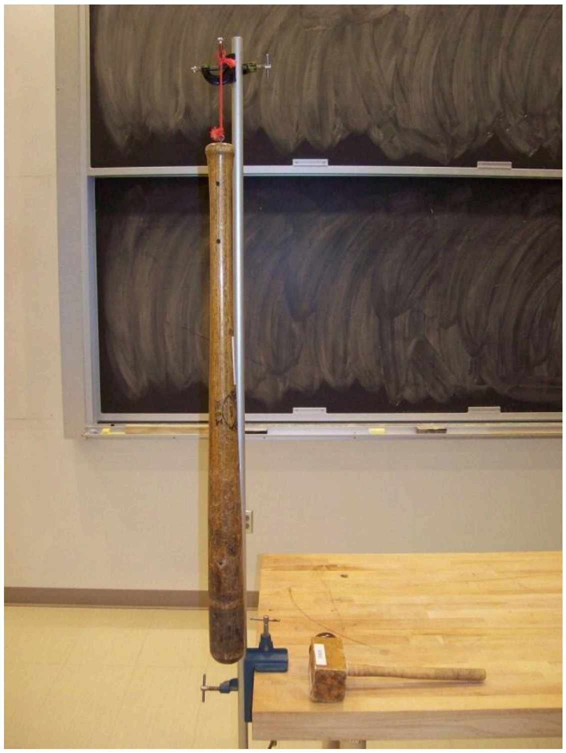
Location: Eb5

OSCILLATIONS AND WAVES	3A15.25	OSCILLATIONS
Physical Pendulum		
# Oscillating Hoop		
	Adjust a simple pendulum to have the same period as a hoop	



Location: EaT

OSCILLATIONS AND WAVES	3A15.50	OSCILLATIONS
Physical Pendulum		
Sweet Spot		
	Hang a baseball bat on a nail through its handle and strike it with a mallet at various spots along the barrel to show the sweet spot (it will sound distinctly different when you hit the sweet spot). Oscillatory period of the bat equals period of simple pendulum of length equal to distance from support to sweet spot.	

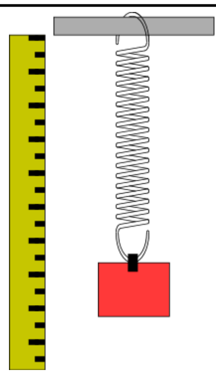


Location: Eb7

OSCILLATIONS AND WAVES	3A20.10	OSCILLATIONS

Springs and Oscillators

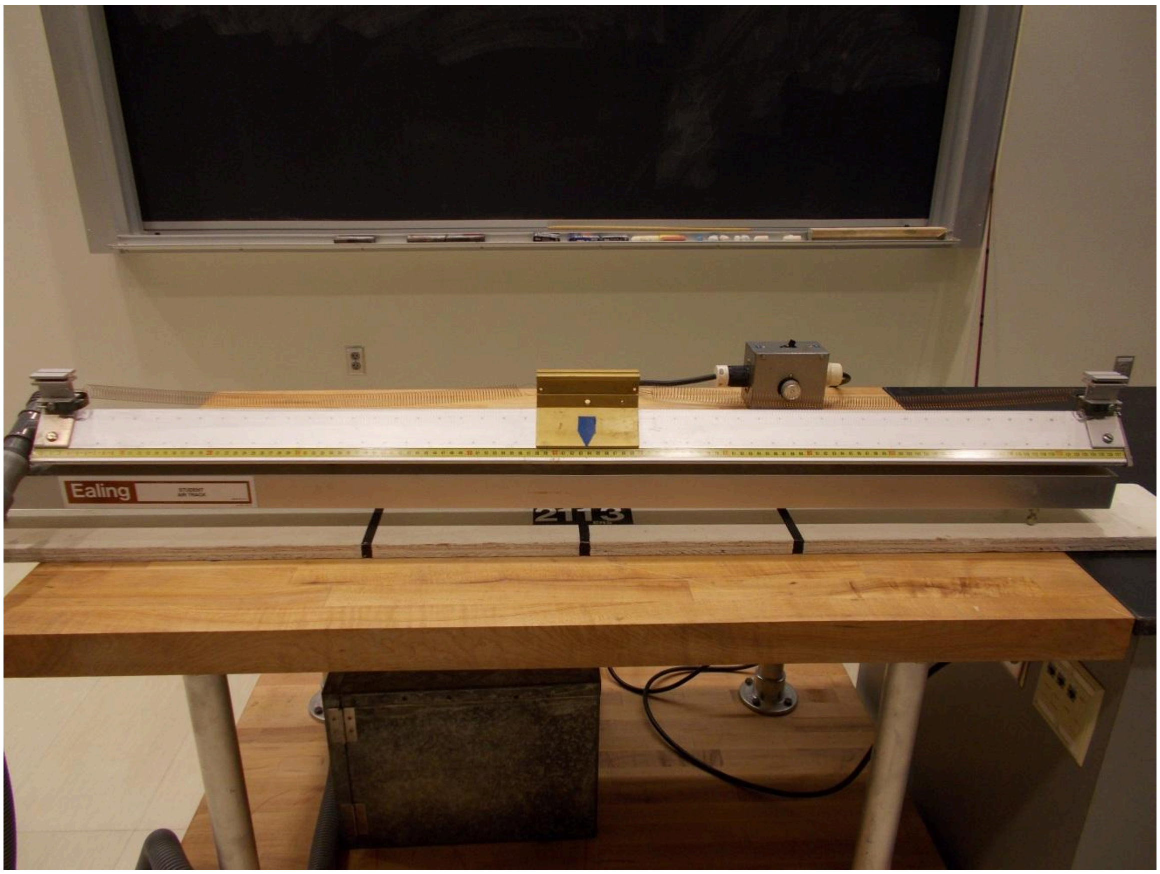
Mass on a Spring



Set up equipment as shown and place a hooked mass on the spring. Pull down and release to start simple harmonic motion. If desired, time the oscillation and calculate the frequency. Change to a different mass in order to change the frequency. The motion can also be plotted using Science Workshop and a motion detector. Some prefer a horizontal mass on a spring.

Location: Eb2

OSCILLATIONS AND WAVES	3A20.35	OSCILLATIONS
Springs and Oscillators		
Air Track Glider Between Springs		
	An air track glider between two springs on an air track. The glider's mass is 0.187 kg. The spring constants are 1.1 N/m.	

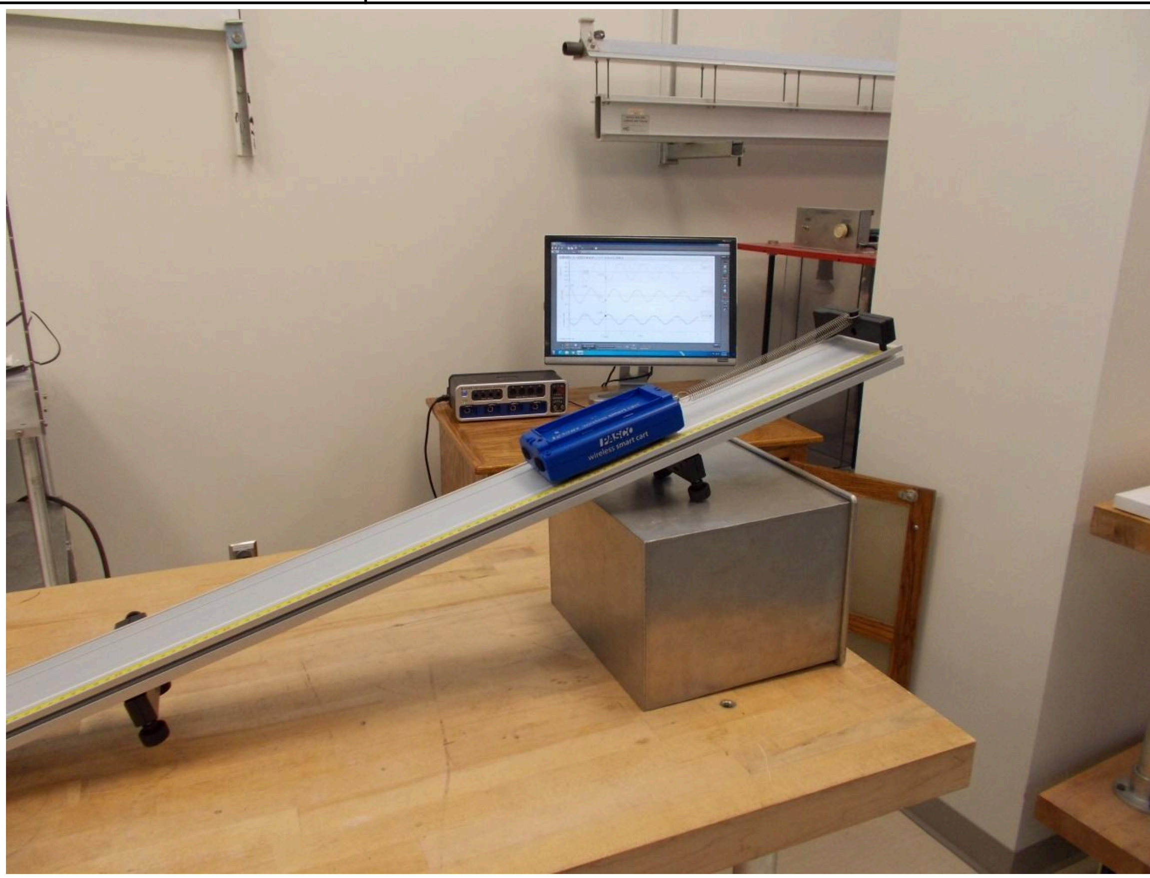


Location: Ac1, EbT

<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3A20.40</td><td>OSCILLATIONS</td></tr>
<tr><td colspan="3">Springs and Oscillators</td></tr>
<tr><td colspan="3"><h1>Roller Cart and Spring</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Attach a large compression spring to a roller cart. The carts mass can be changed by adding masses.</td></tr>
</table>

Location: Cb1, Eb2

OSCILLATIONS AND WAVES	3A20.45	OSCILLATIONS
Springs and Oscillators		
# Smart Cart Oscillator		
	A smart Cart is attached to a spring on an inclined track and its motion is plotted. The Capstone file is "Smart Cart Oscillator.cap"	

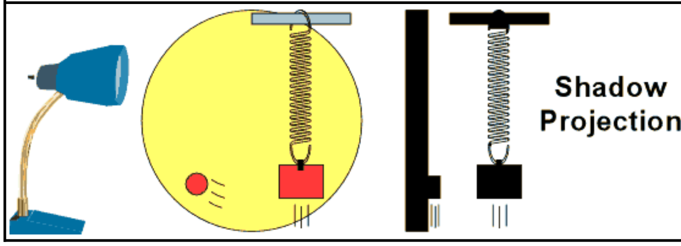


Location: Bb2, Cb1

OSCILLATIONS AND WAVES	3A40.10	OSCILLATIONS

Simple Harmonic Motion

Circular Motion vs. Mass on a Spring



Shadow project a ball at the edge of a disc rotating at the same frequency as a mass on a spring.

Location: Eb2, Jd3

OSCILLATIONS AND WAVES	3A40.50	OSCILLATIONS
Simple Harmonic Motion		

SHM with Motion Sensor

	A mass on a spring's motion is measured with an ultrasonic ranger and a force sensor. The net force, displacement, and velocity vs. time are shown in graphs. The mass used is 0.408 kg. The spring constant is 14.2 n/m. The Capstone file is SHM with Force Sensor.

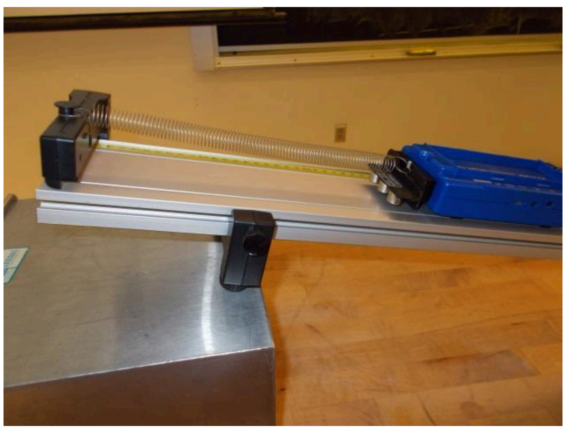
Location: Science Workshop Cabinet, Eb2

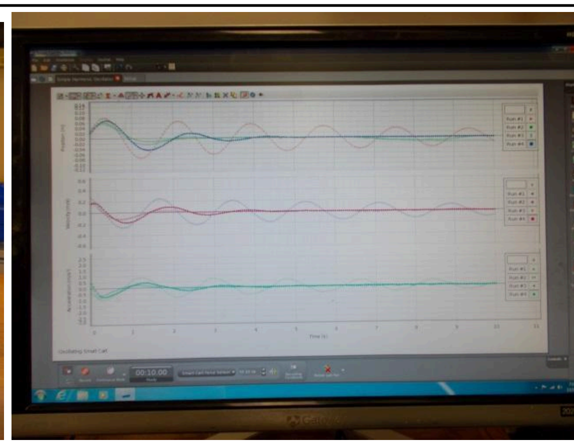
OSCILLATIONS AND WAVES	3A50.20	OSCILLATIONS

Damped Oscillators

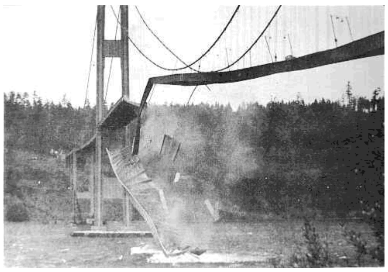
Damped SHM Tracer

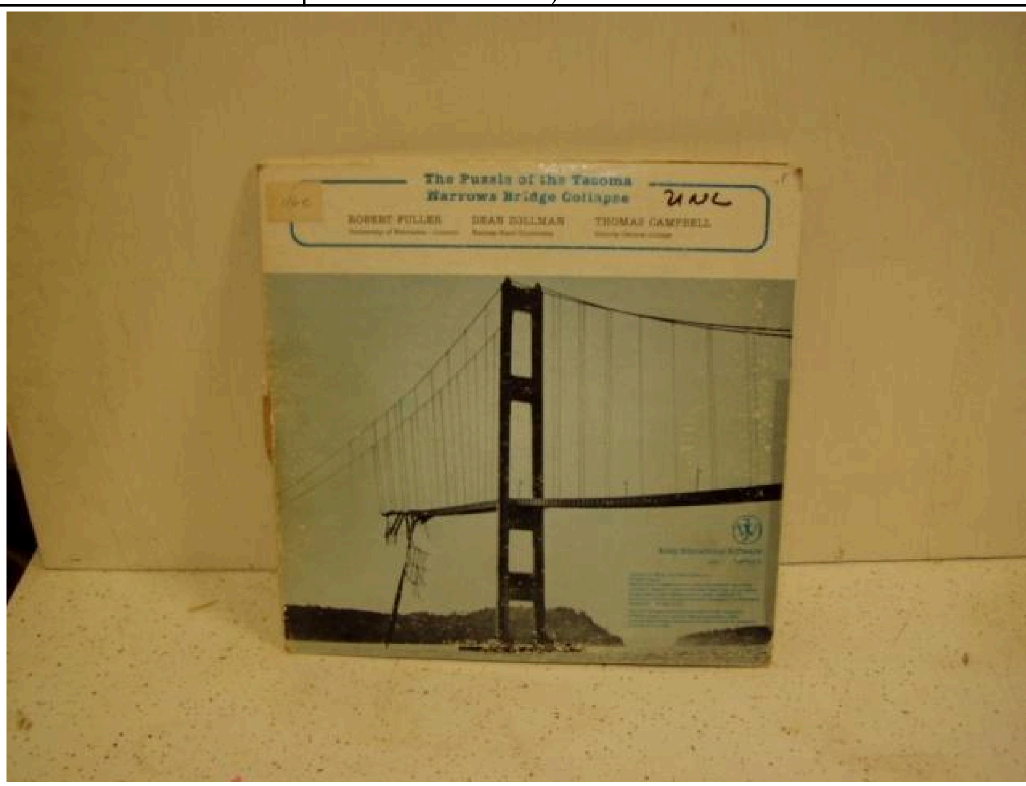
	A cart is connected to a spring and its displacement, velocity and acceleration are measured with a Smart Car; the Capstone file is “Smart Cart Oscillator.cap”. The damping may be changed by moving the magnets closer or further from the aluminum track





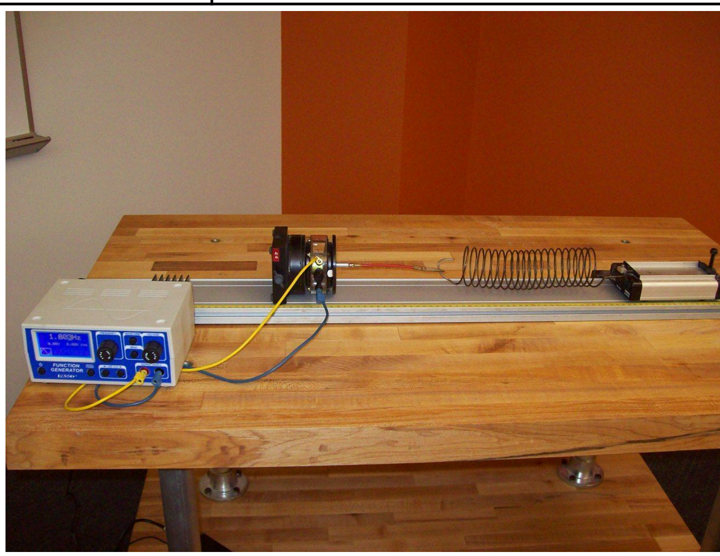
Location: Science Workshop Cabinet, Bb2, Cb1

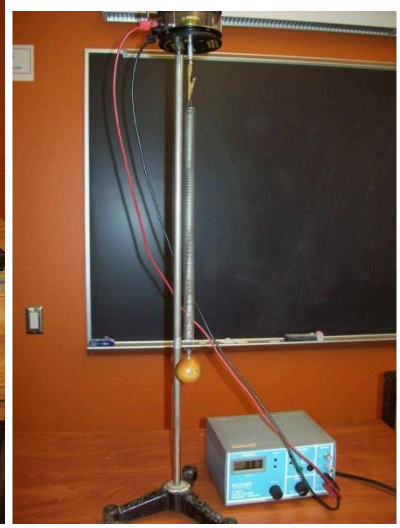
<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3A60.10</td><td>OSCILLATIONS</td></tr>
<tr><td colspan="3">Driven Mechanical Resonance</td></tr>
<tr><td colspan="3">Tacoma Narrows Film/Video</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">The "dead dog" version runs ten minutes on video disk. The film loop runs 4:40.The entire film can be purchased from http://www.camerashoptacoma.com/narrows.asp
8 sec clips can be found online at
http://www.stkate.edu/physics/phys111/curric/tacomabr.html
If you are using this to illustrate driven mechanical resonance, I strongly suggest you read some of the references (one is stored with the video disk).</td></tr>
</table>



Location: Video Cabinet

OSCILLATIONS AND WAVES	3A60.40	OSCILLATIONS
Driven Mechanical Resonance		
Driven Mass on a Spring		
	A Pasco driver and oscillator/amplifier is used to drive a dynamics cart connected to a spring. This can also be done with less damping using a ball hanging from a spring driven by the same equipment. The motion can be plotted on the computer using Science Workshop and a Motion Detector. The resonant frequency is about 1.8 Hz. Also shown is the vertical version, resonance at 0.887 Hz.	



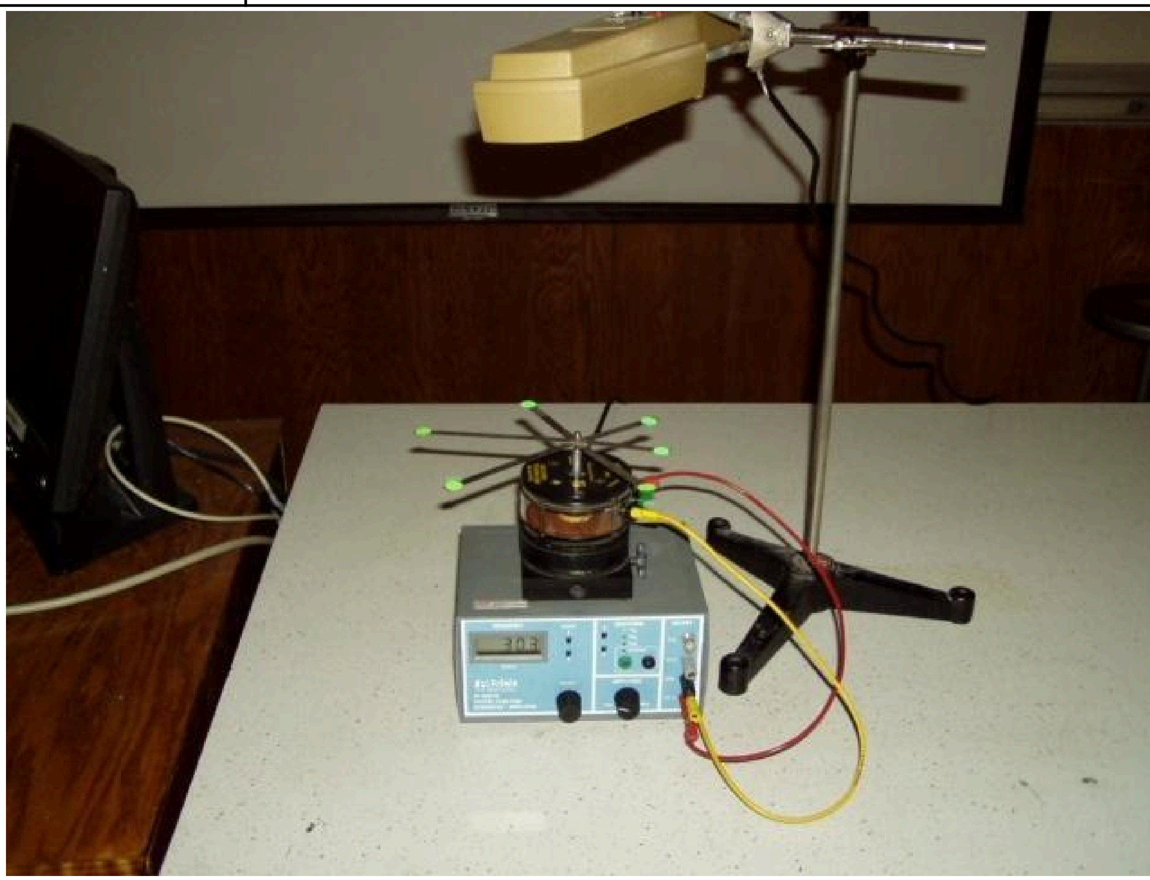


Location: Eb2, Eb3, Fb4

OSCILLATIONS AND WAVES	3A60.50	OSCILLATIONS
Driven Mechanical Resonance		

Resonance Reeds

	A Pasco driver and oscillator/amplifier is used to drive a set of spring steel strips of differing lengths. Frequencies: 22 Hz, 27 Hz, 30 Hz, 47 Hz, 63 Hz, 80 Hz. The black light makes the movement of the ends of the strip more visible.



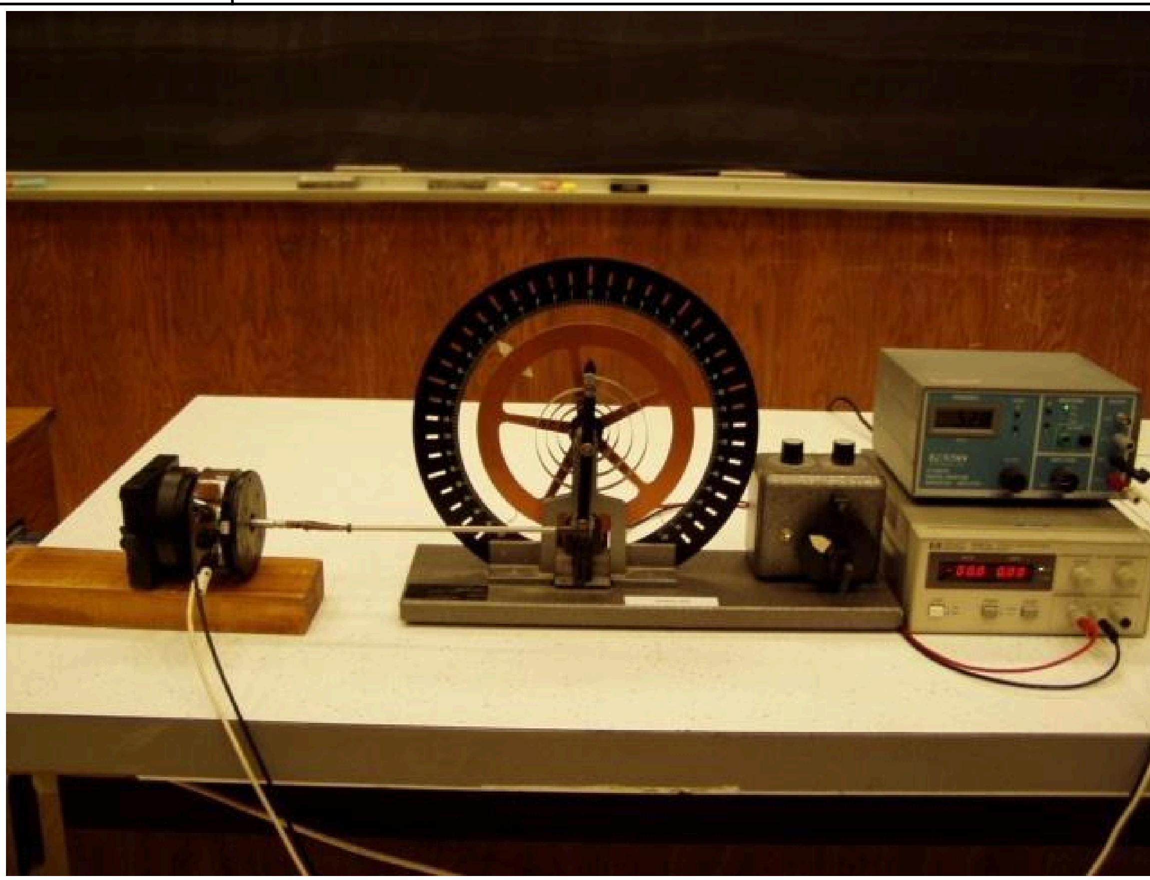
Location: Eb3, Fb4

OSCILLATIONS AND WAVES	3A60.55	OSCILLATIONS

Driven Mechanical Resonance

Driven Torsion Pendulum

A Pasco driver and oscillator/amplifier is used to drive a torsional oscillator. The oscillator, a copper annulus, can be damped using a built in electromagnet (use no more than 1 ampere of current through the electromagnet). The undamped resonant frequency is 0.515 Hz. The relationship between the driver and oscillator can be seen by observing the pointers on the driver and on the oscillating copper annulus.

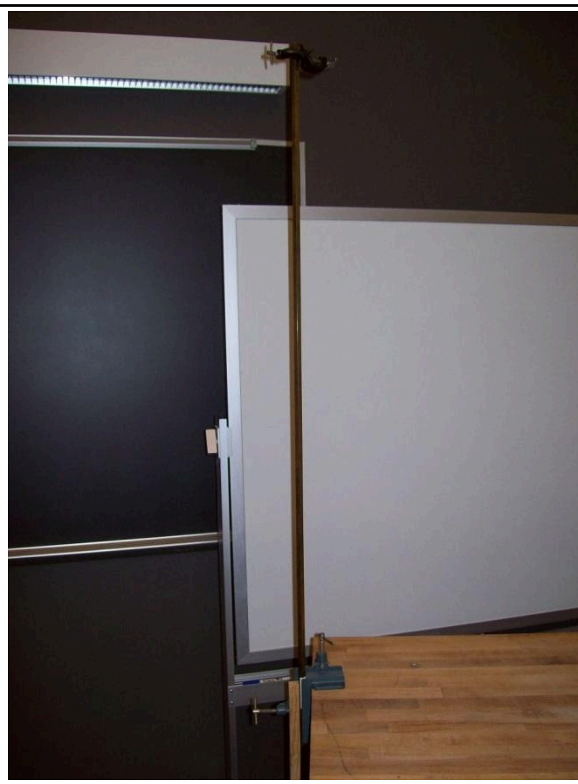


Location: Eb7, Fb4

OSCILLATIONS AND WAVES	3A60.70	OSCILLATIONS
Driven Mechanical Resonance		

Lamppost Resonance

	A brass bar is firmly vertically clamped to the table. There is also a clamp at the top of the rod that serves as a mass. The bar can then be driven at its base by hand to large amplitudes if it is driven at its resonant frequency.



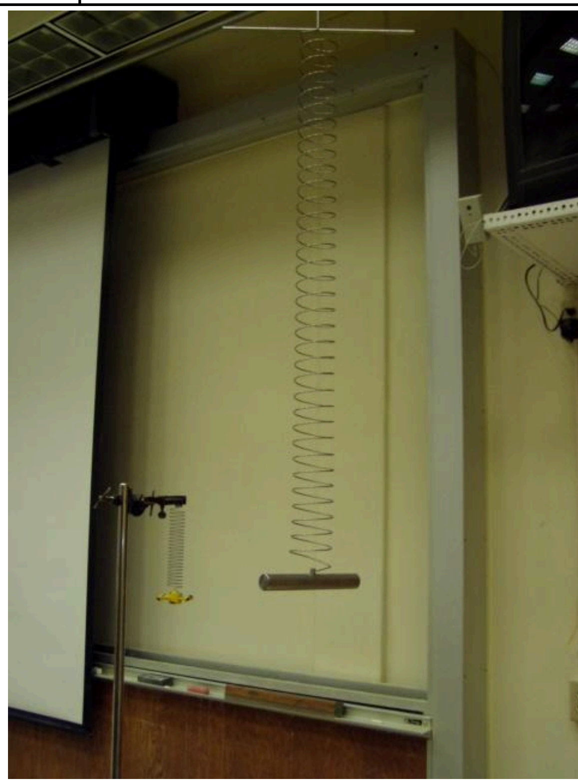
Location: Cc1

OSCILLATIONS AND WAVES	3A70.10	OSCILLATIONS

Coupled Oscillations

Wilberforce Pendulum

	Transfer of energy between torsional and vertical oscillation of a Wilberforce pendulum. Also shown in the photograph is a large similar device that couples the spring's motion to two horizontal bars.

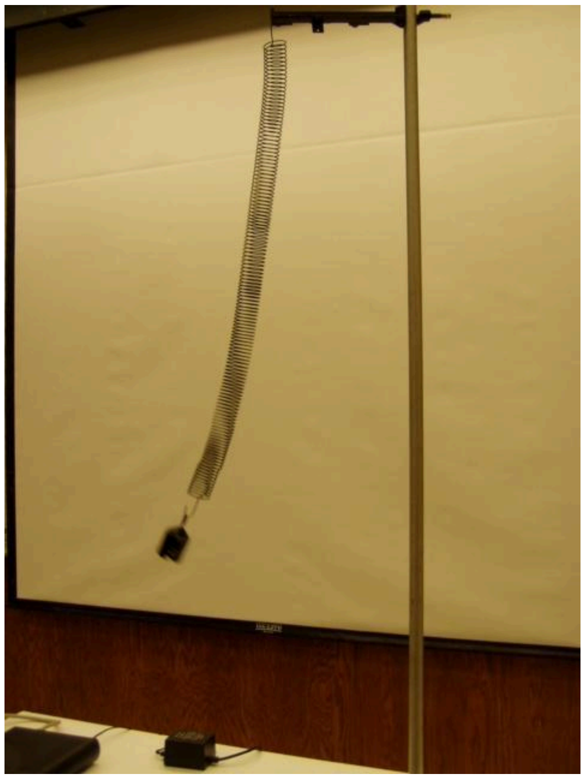


Location: Eb3

OSCILLATIONS AND WAVES	3A70.15	OSCILLATIONS
Coupled Oscillations		

Swinging Mass on a Spring

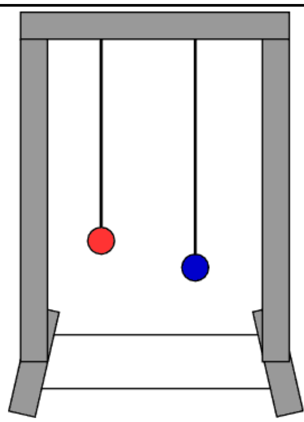
	Autoparametric resonance occurs when the rest length of a spring is stretched by about one third by a hanging mass.



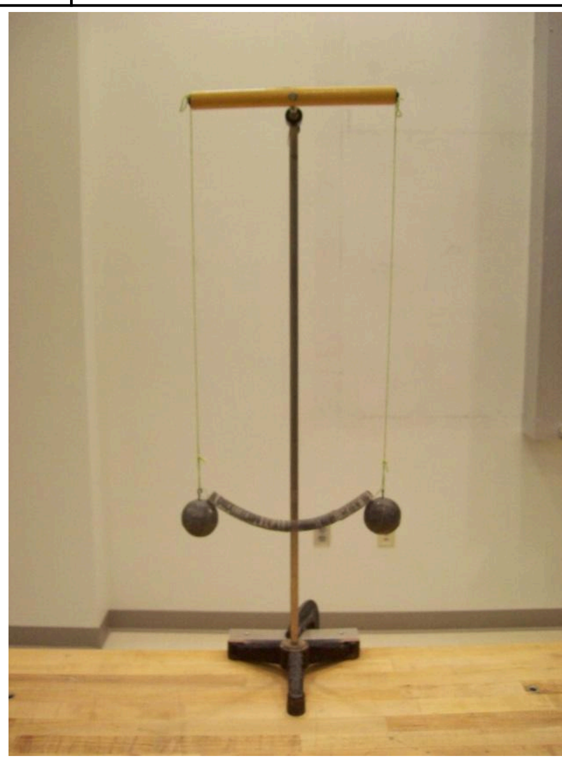
Location: Eb2

Coupled Oscillations

Coupled Pendula



Two pendula hang from a flexible metal frame. Start one pendulum oscillating. The pendula will pass the energy back and forth. A spring connecting the two masses can be used to increase the coupling.



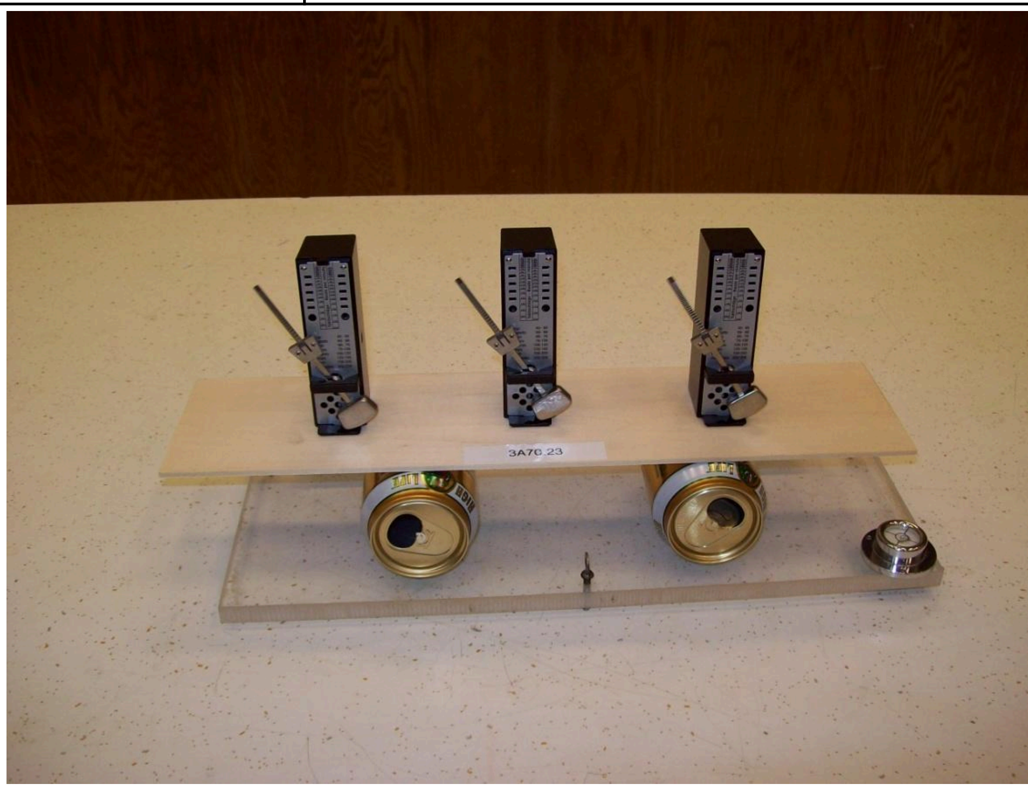
Location: Eb4

OSCILLATIONS AND WAVES	3A70.23	OSCILLATIONS

Coupled Oscillations

Synchronization of Metronomes

	Three metronomes are adjusted to beat out 208 ticks per minute. They are placed on a light board and their lack of synchronization is noted. The board is then lifted with the metronomes on it and placed on two cans that serve as bearings. It is important that the surface the cans are on is level and smooth. After a minute or two, the metronomes will beat in synch.

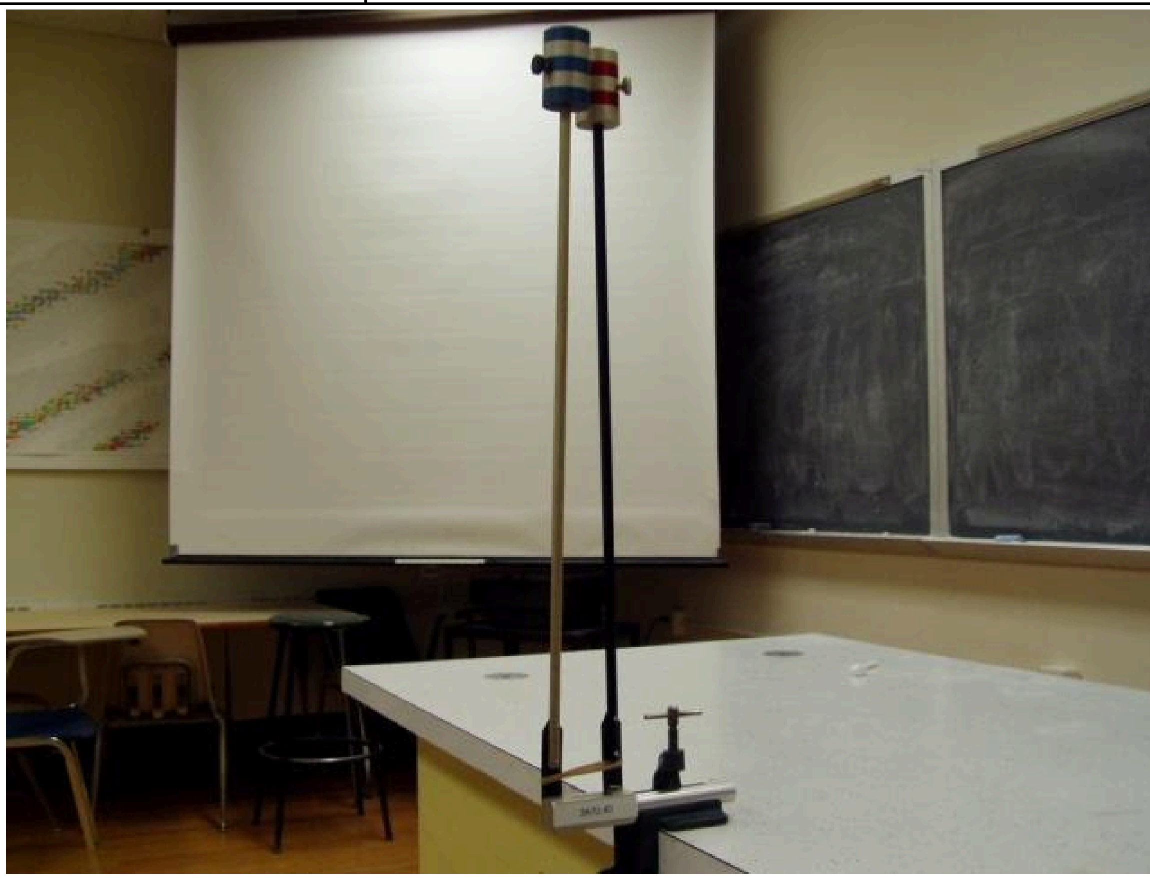


Location: Eb4

OSCILLATIONS AND WAVES	3A70.40	OSCILLATIONS
Coupled Oscillations		

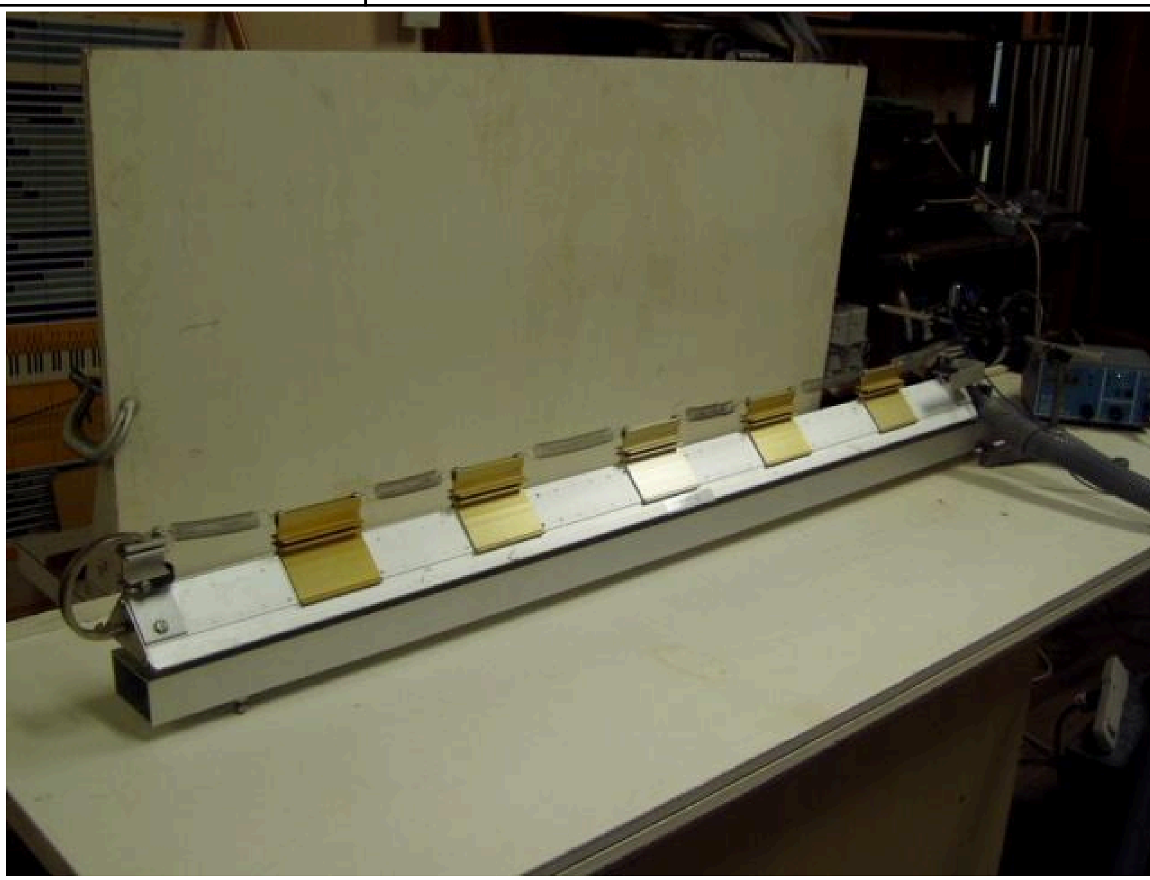
Inverted Coupled Pendula

	Two vertical metal strips support rods that can be coupled together with rubber bands. Masses can be placed along the rods so that beats can be seen as the masses oscillate.



Location: Eb4

OSCILLATIONS AND WAVES	3A75.10	OSCILLATIONS
Normal Modes		
# Coupled Harmonic Oscillators		
	Several identical air track gliders are coupled with identical springs. Show the various normal modes. Frequencies: f0 = 0.400 Hz (all move together); f1 = 0.777 Hz (middle stationary, outer two on each side move together); f2 = 1.100 Hz (outertmost and middle moving, other two stationary); f3 = 1.348 Hz (Middle stationary, outer one moving but in opposition to each other); f4 = 1.503 Hz (all moving, the middle and outer two in opposition to the other two).	



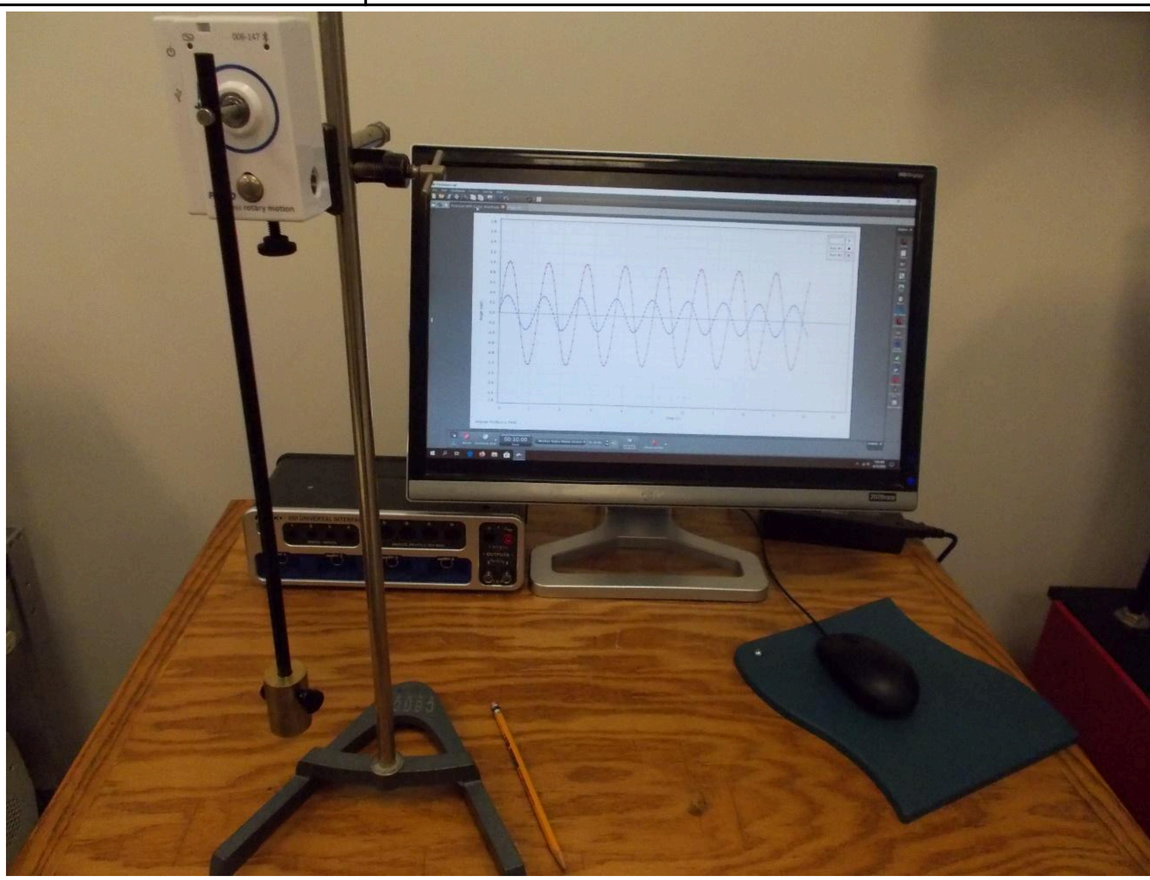
Location: EbT, Fb4

OSCILLATIONS AND WAVES	3A95.33	OSCILLATIONS

Non-Linear Systems

Pendulum with Large Amplitude

A pendulum's motion is measured with a rotary sensor and is plotted with the Capstone software (Pendulum with Large Amplitude.cap). Pull the bob to the left with a large amplitude (say 90 degrees) and release it; the software will start recording when the bob passes the zero degree point. Then repeat the experiment using a small amplitude and compare the two angular position vs. time plots.

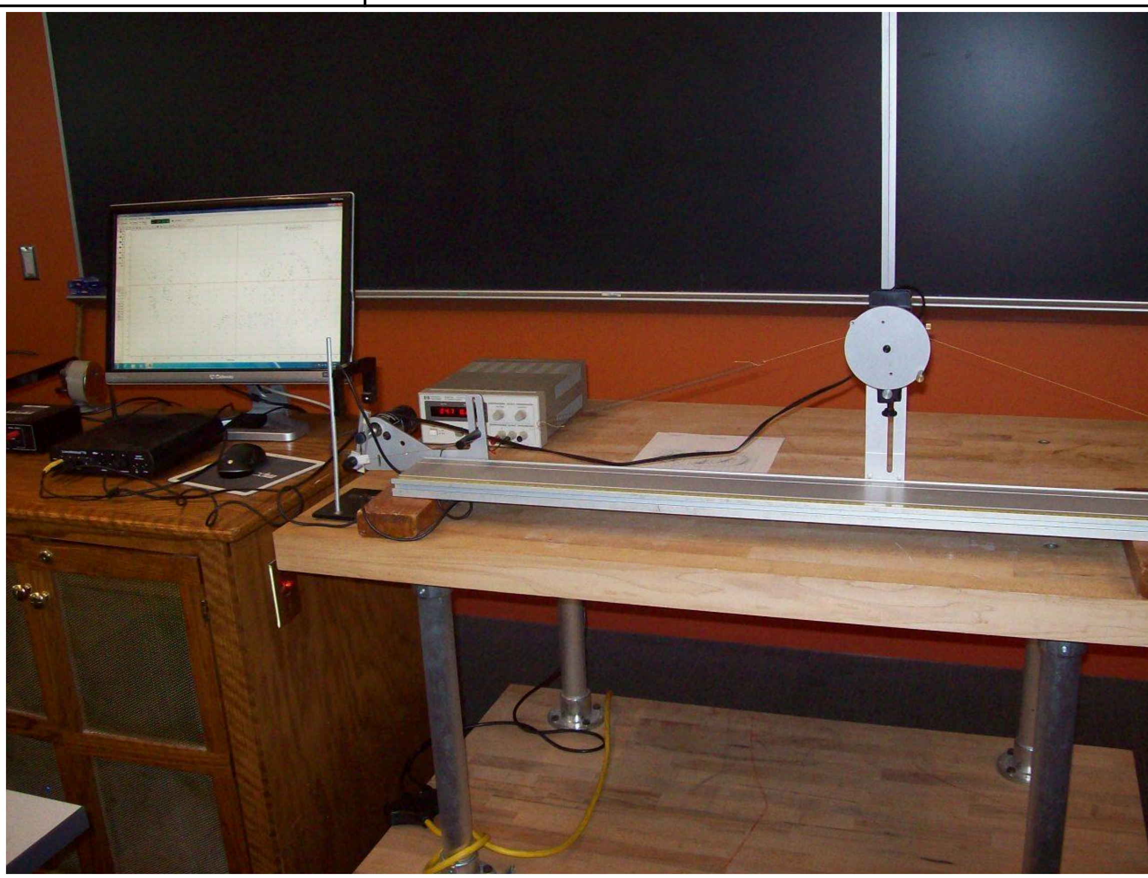


Location: Eb5

OSCILLATIONS AND WAVES	3A95.52	OSCILLATIONS
Non-Linear Systems		

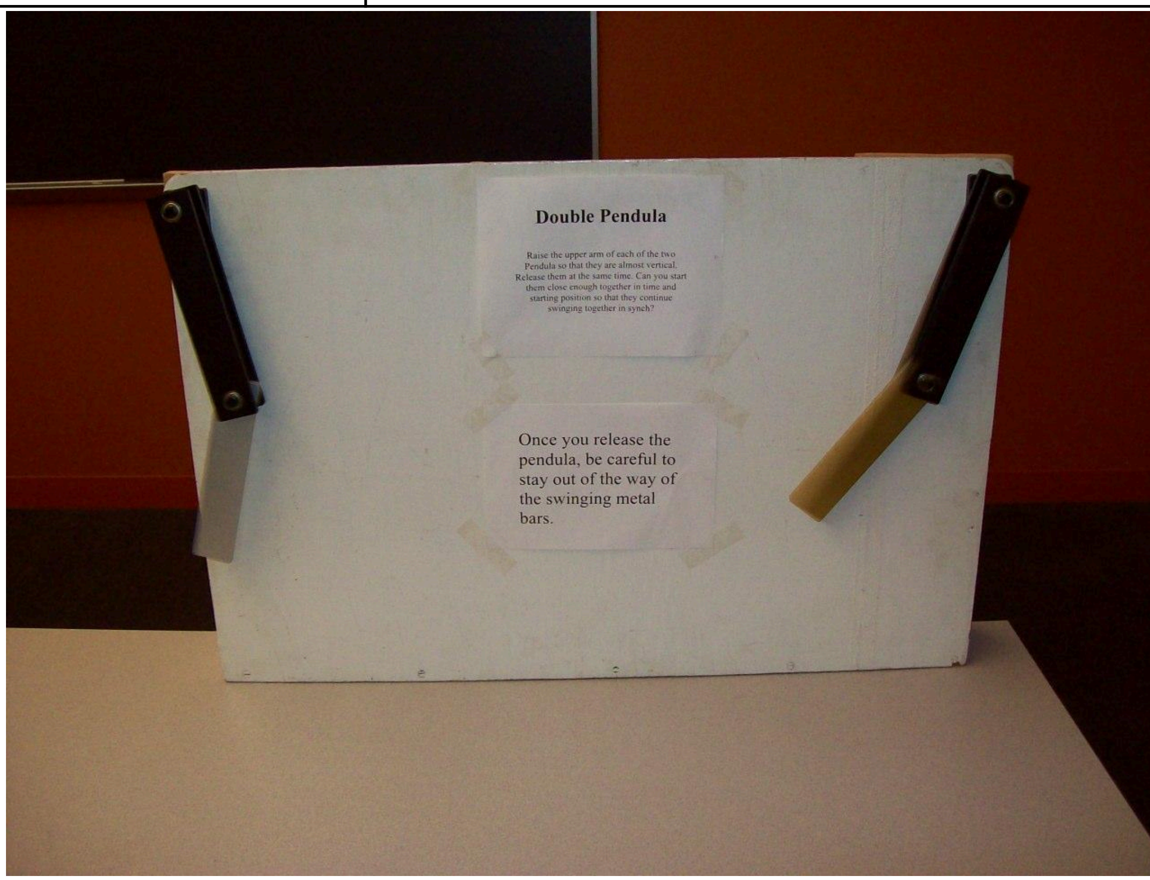
Chaotic Oscillator

A chaotic oscillator is connected to a computer using Science Workshop and a Poincare Section of a phase space plot is created. For the equipment as shown, the motor voltage was 4.2 V (a rotation period of about 1.4 s for the motor). The plot is started at top dead center with the driver at 0 degrees phase (blocking the photo gate). The springs and string is adjusted so that the unstable neutral position is when the weight on the disc pendulum is at the top.



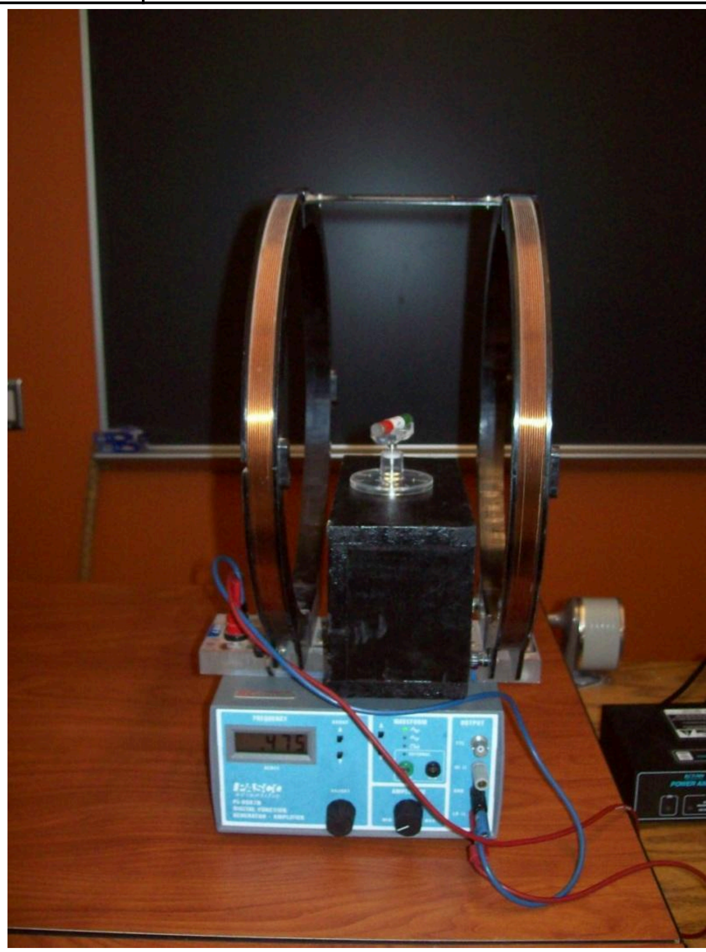
Location: Science Workshop Cabinet, Eb5, AcT

OSCILLATIONS AND WAVES	3A95.56	OSCILLATIONS
	Non-Linear Systems	
	Chaotic Double Pendulum	
	Two double Pendula are mounted side by side. The sign reads: "Raise the upper arm of each of the two Pendula so that they are almost vertical. Release them at the same time. Can you start them close enough together in time and starting position so that they continue swinging together in synch?"	



Location: Eb7

OSCILLATIONS AND WAVES	3A95.57	OSCILLATIONS
Non-Linear Systems		
Chaotic Compass		
	A magnet on a pivot is driven by an oscillating magnetic field at about 0.5 Hz.	



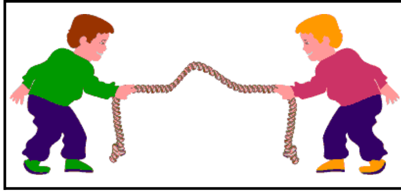
Location: Fb4, Hb7, Hc1

OSCILLATIONS AND WAVES	3B10.10	WAVE MOTION

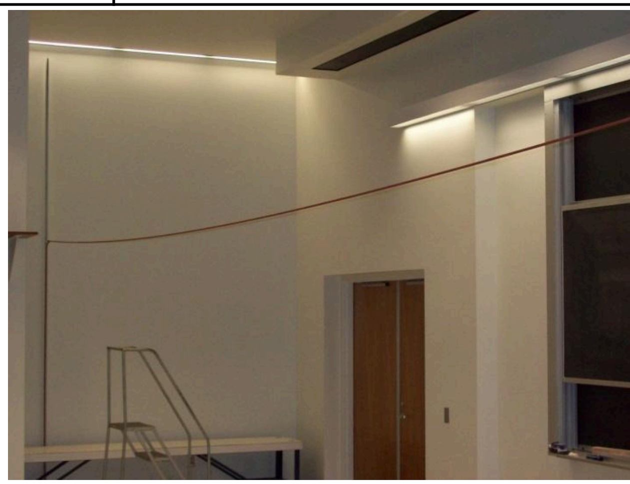
Transverse Pulses and Waves

Pulse on a Rope or Spring

Disc 09-09

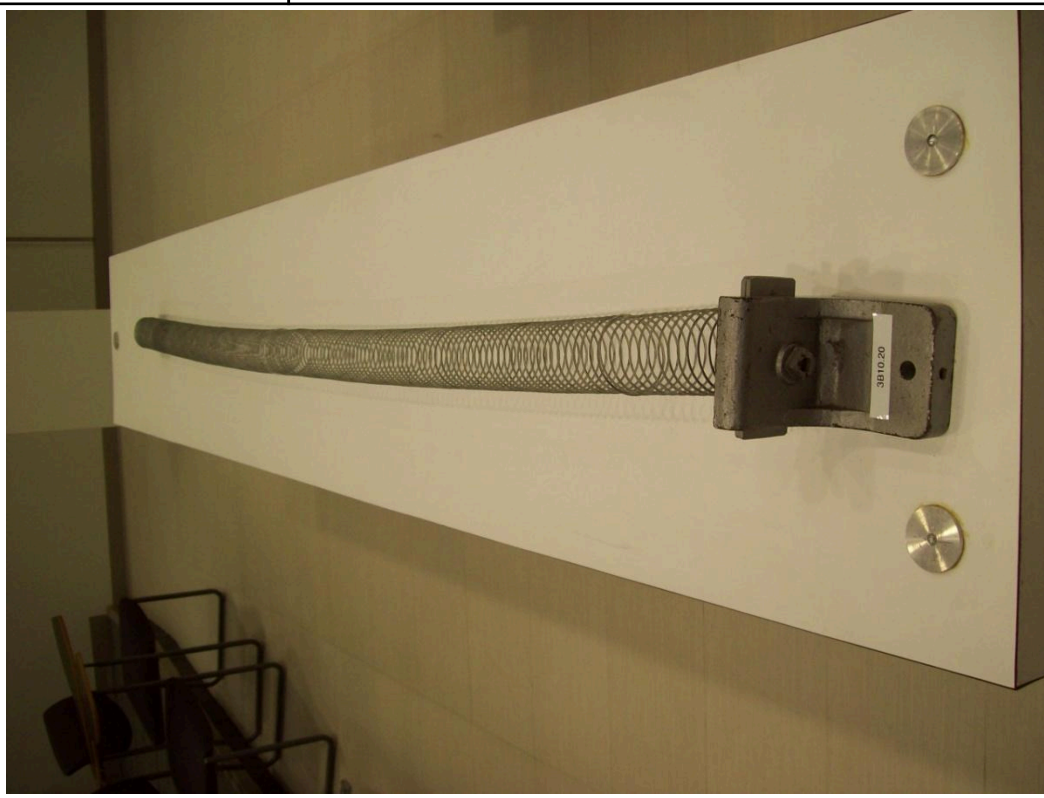


A long rope or spring runs the width of the lecture hall. One end is held steady. Jerk the other end of the rope up and down to create a pulse. The spring will also nicely show longitudinal pulses.

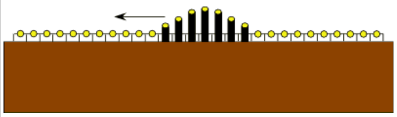


Location: Eb6

OSCILLATIONS AND WAVES	3B10.20	WAVE MOTION
Transverse Pulses and Waves		
Slinky on a Table		
	Create pulses and waves by hand on a slinky stretched down the lecture table.	



Location: Eb6

OSCILLATIONS AND WAVES	3B10.30	WAV MOTION
Transverse Pulses and Waves		
Shive / Bell Labs Wave Model		
Disc 09-12		
	Thin rods are mounted on a fine wire that twists easily. Displace the rod at one end to create a torsion pulse or wave. The other end can the left free to move, fixed in place, or critically damped.	

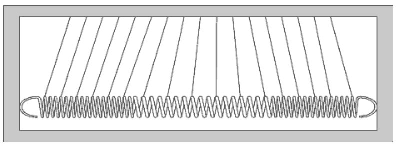
Location: Ec1

OSCILLATIONS AND WAVES	3B20.10	WAVE MOTION

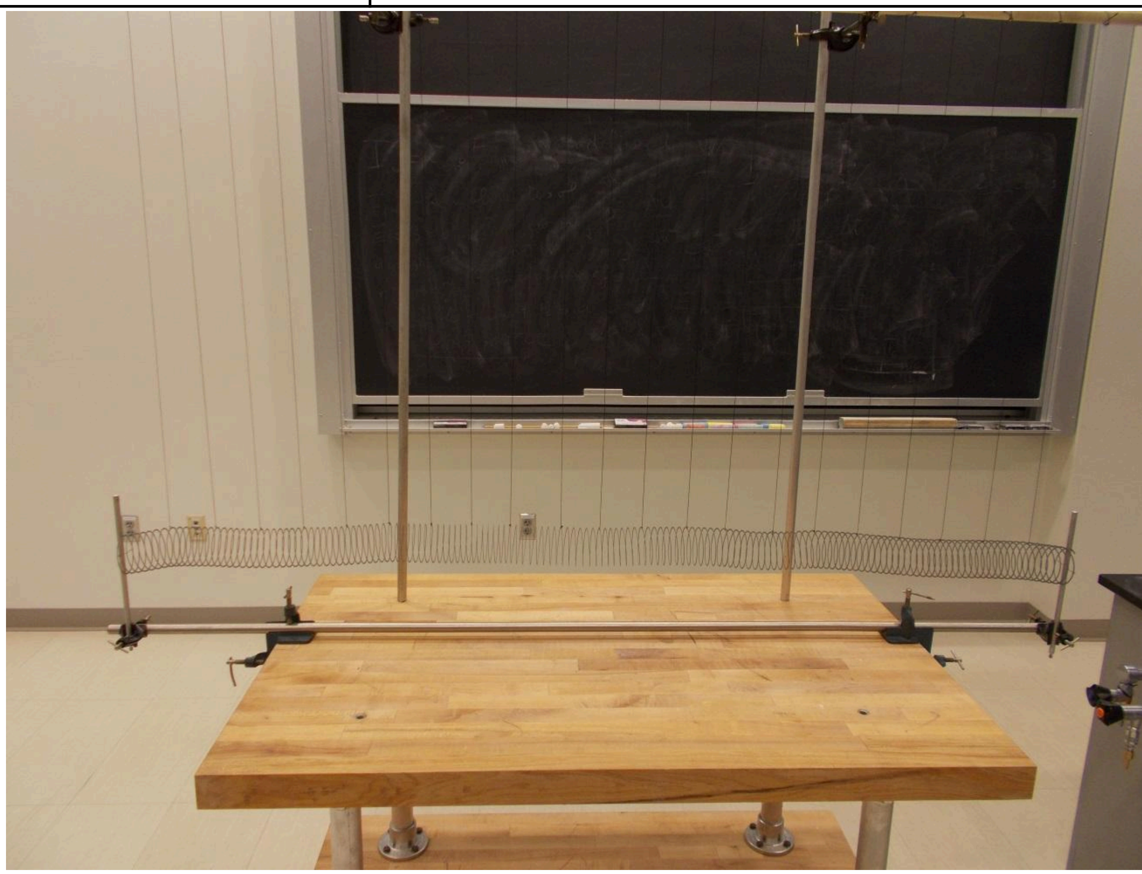
Longitudinal Pulses and Waves

Hanging Slinky

Disc 09-15

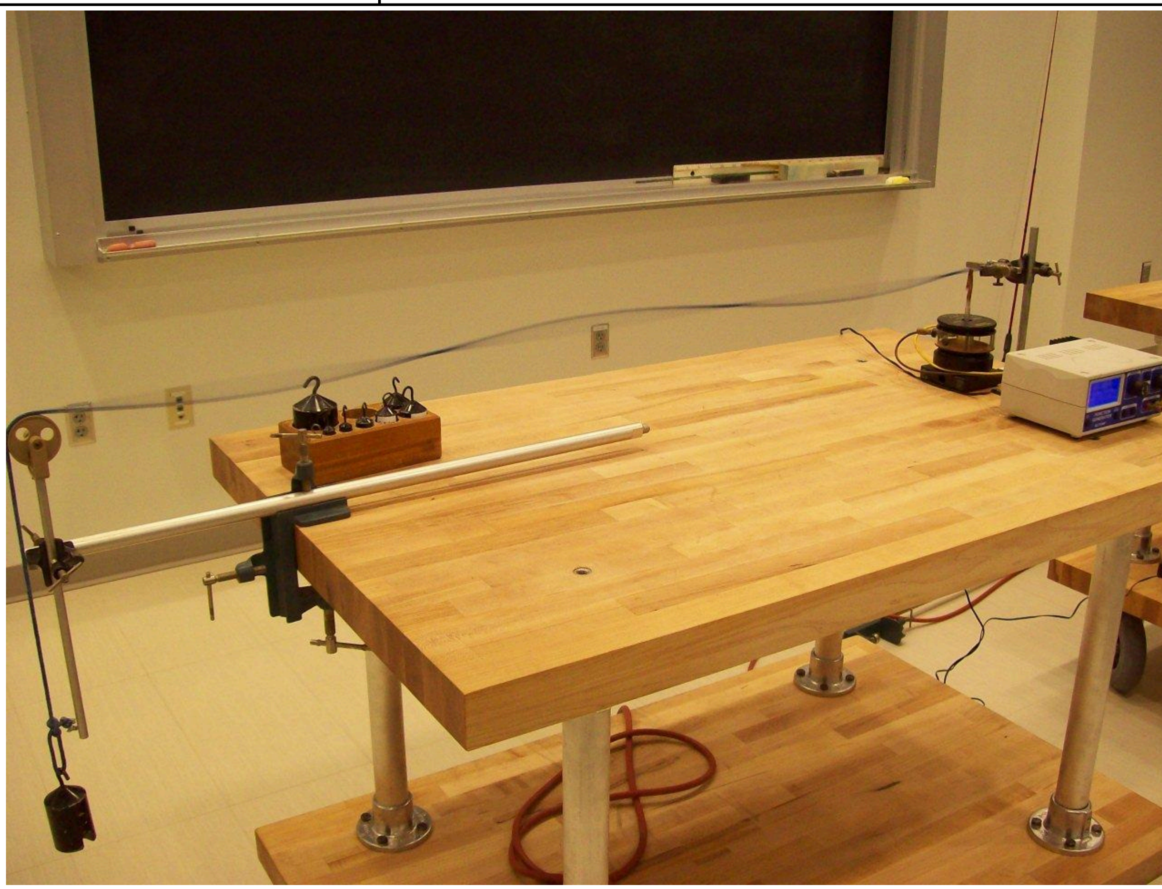


A long slinky is suspended along a frame. Stretch and compress the spring quickly to create a pulse or wave. A spot can be attached to the spring to show that the wave travels and the medium only oscillates.



Location: EcT

<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3B22.10</td><td>WAVE MOTION</td></tr>
<tr><td colspan="3">Standing Waves</td></tr>
<tr><td colspan="3"><h1>Melde's Apparatus</h1></td></tr>
<tr><td colspan="3">Disc 09-27, 09-28</td></tr>
<tr><td></td><td colspan="2">A string is help under tensions and driven by a variable frequency oscillator. Changing the frequency will change the number of modes. A strobe can be used to see the waves.</td></tr>
</table>



Location: Ec2, Fb4

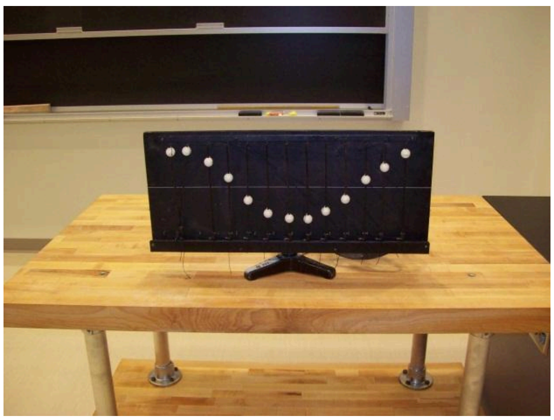
OSCILLATIONS AND WAVES	3B22.50	WAVE MOTION
Standing Waves		
Slinky Standing Waves		
	Drive a hanging slinky by hand to produce longitudinal standing waves.	

Location: EcT

OSCILLATIONS AND WAVES	3B22.90	WAVE MOTION
Standing Waves		

Crank Slide, Russian Wave Machine

	A projection device that gives the appearance of waves traveling in the opposite directions and the sum of the waves. The Russian wave machine is cranked by hand and can simulate standing and traveling transverse and longitudinal waves.



Location: Ec3

OSCILLATIONS AND WAVES	3B25.10	WAVE MOTION
Impedance and Dispersion		
Impedance Matching		
	Two sections of horizontal torsion machine with different lengths are joined abruptly together for unmatched coupling and with a section of gradually lengthening rods for matched coupling.	

Location: Ec1

OSCILLATIONS AND WAVES	3B25.11	WAVE MOTION
Impedance and Dispersion		

Wave Reflection at a Discontinuity

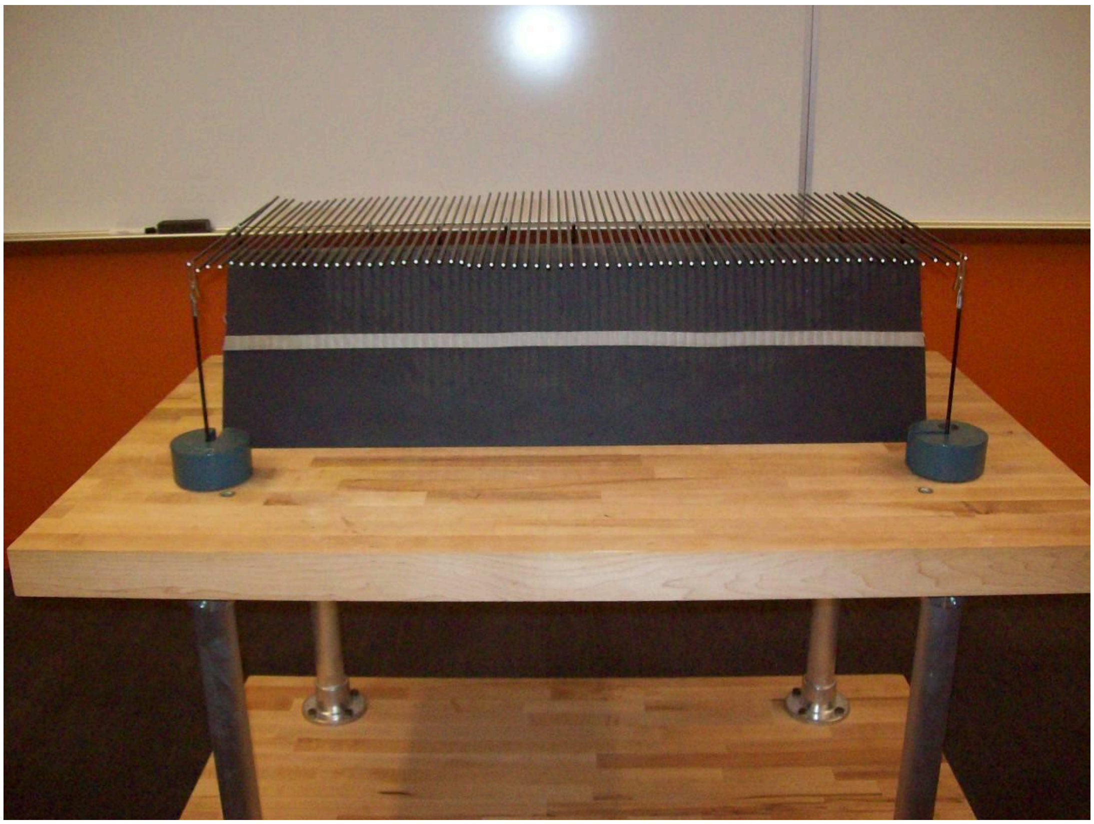
	Two Shive wave machines with different length rods are hooked together.

Location: Ec1

OSCILLATIONS AND WAVES	3B25.20	WAVE MOTION
Impedance and Dispersion		

Reflection – Shive Model

	A pulse sent down a Shive machine reflects from either a fixed or free end.

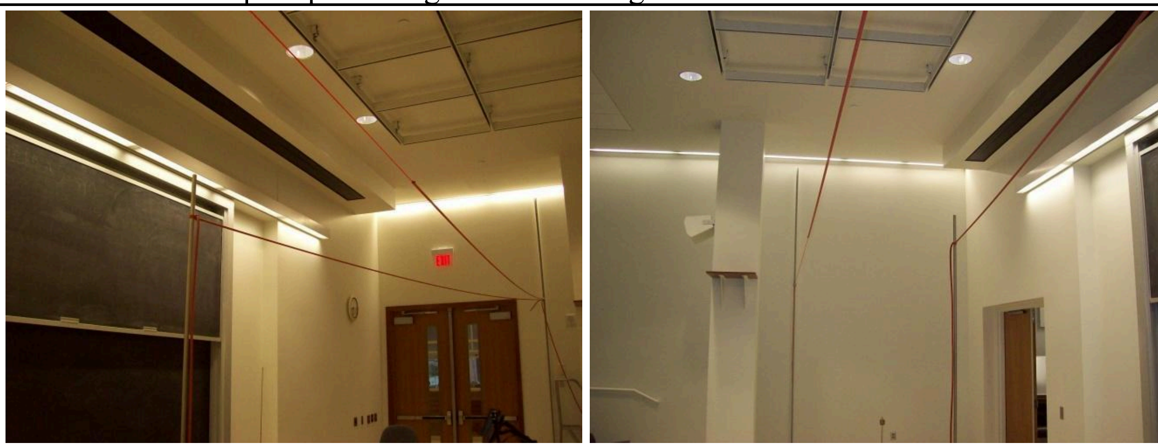


Location: Ec1

OSCILLATIONS AND WAVES	3B25.26	WAVE MOTION
Impedance and Dispersion		

Fixed and Free Rope Reflection

	Tie a rubber rope to a light rope and watch the shape of the pulse resulting from giving the rubber rope a sharp rap with a meter stick near its tied end. Compare to the rope with no light rope section. One can also set up standing waves showing the free end condition.

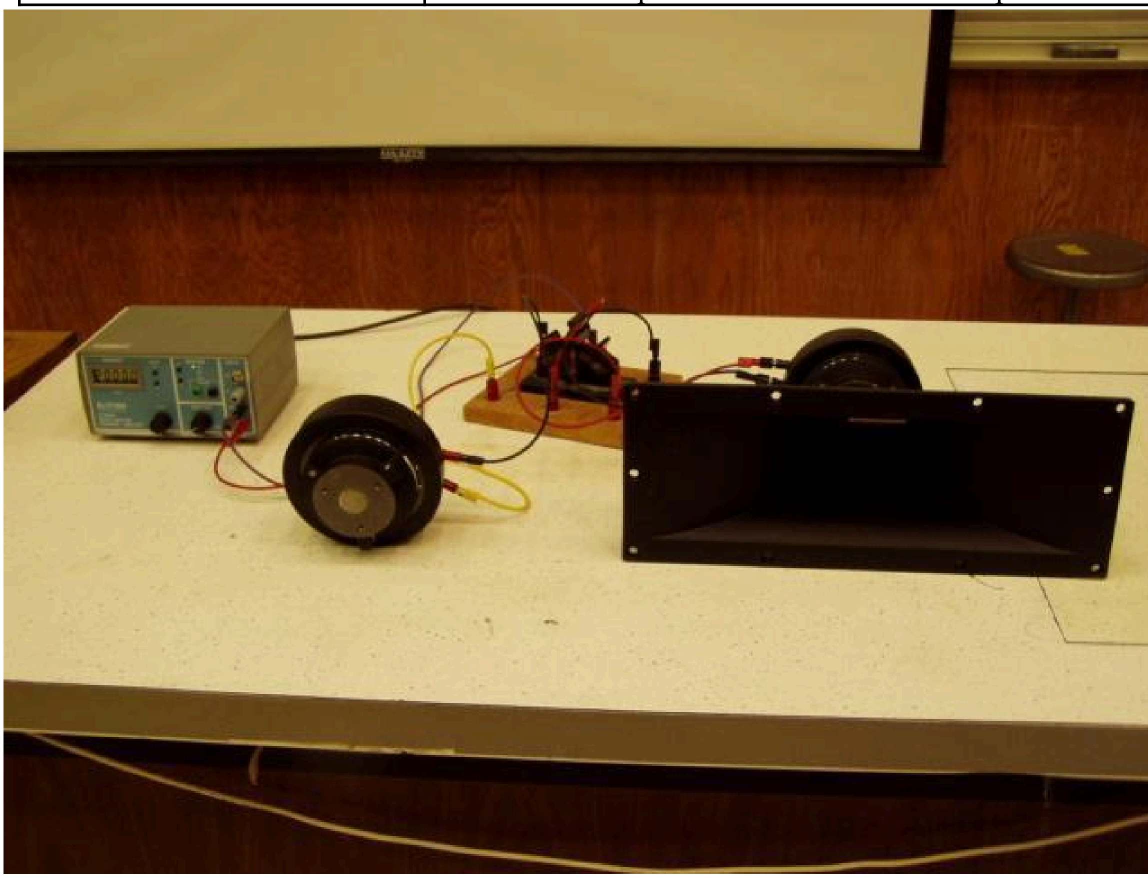


Location: Ec4

OSCILLATIONS AND WAVES	3B25.35	WAVE MOTION
Impedance and Dispersion		

Acoustic Coupling

	Sound a 1 inch speaker alone and with an exponential horn.

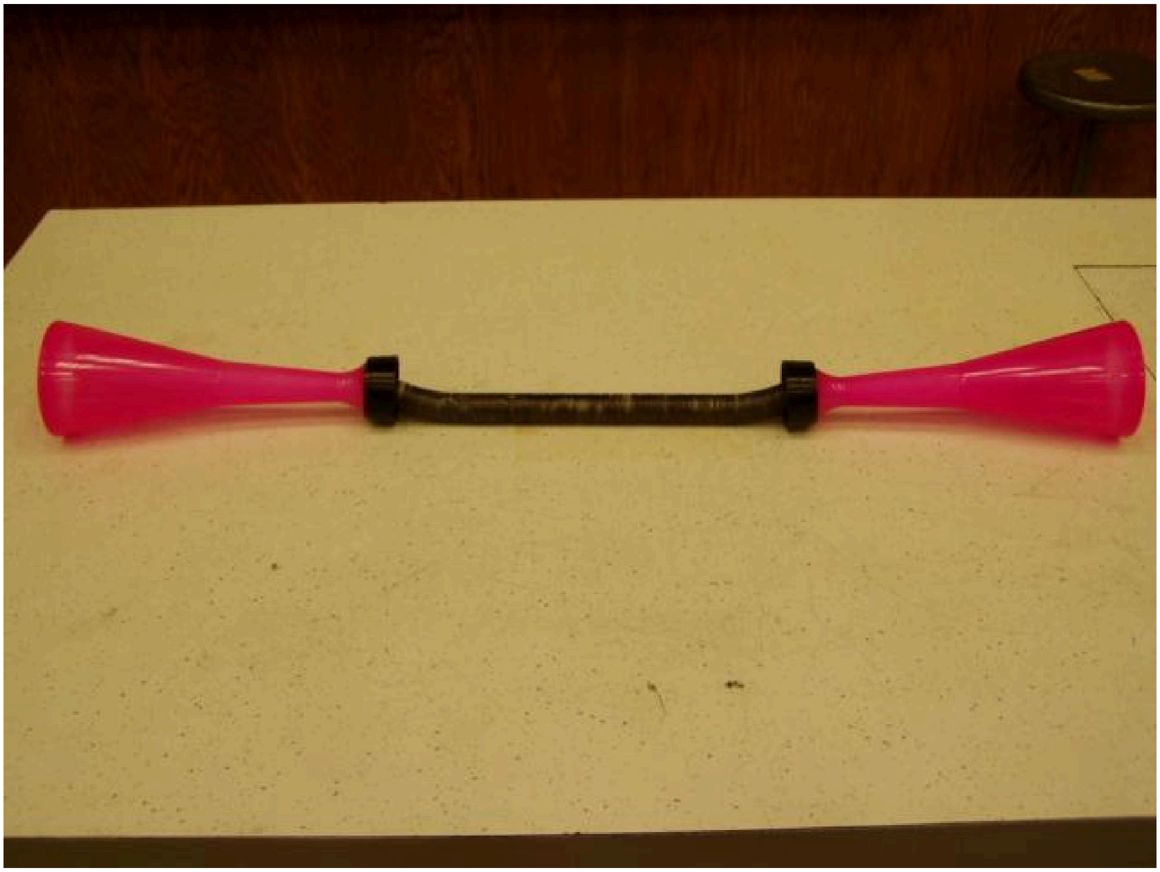


Location: Ec4, Fb4

OSCILLATIONS AND WAVES	3B25.55	WAVE MOTION
Impedance and Dispersion		

Space Phone

	A long helical spring transmits sound slowly. Speak into one end and the sound emerges distorted at the other.



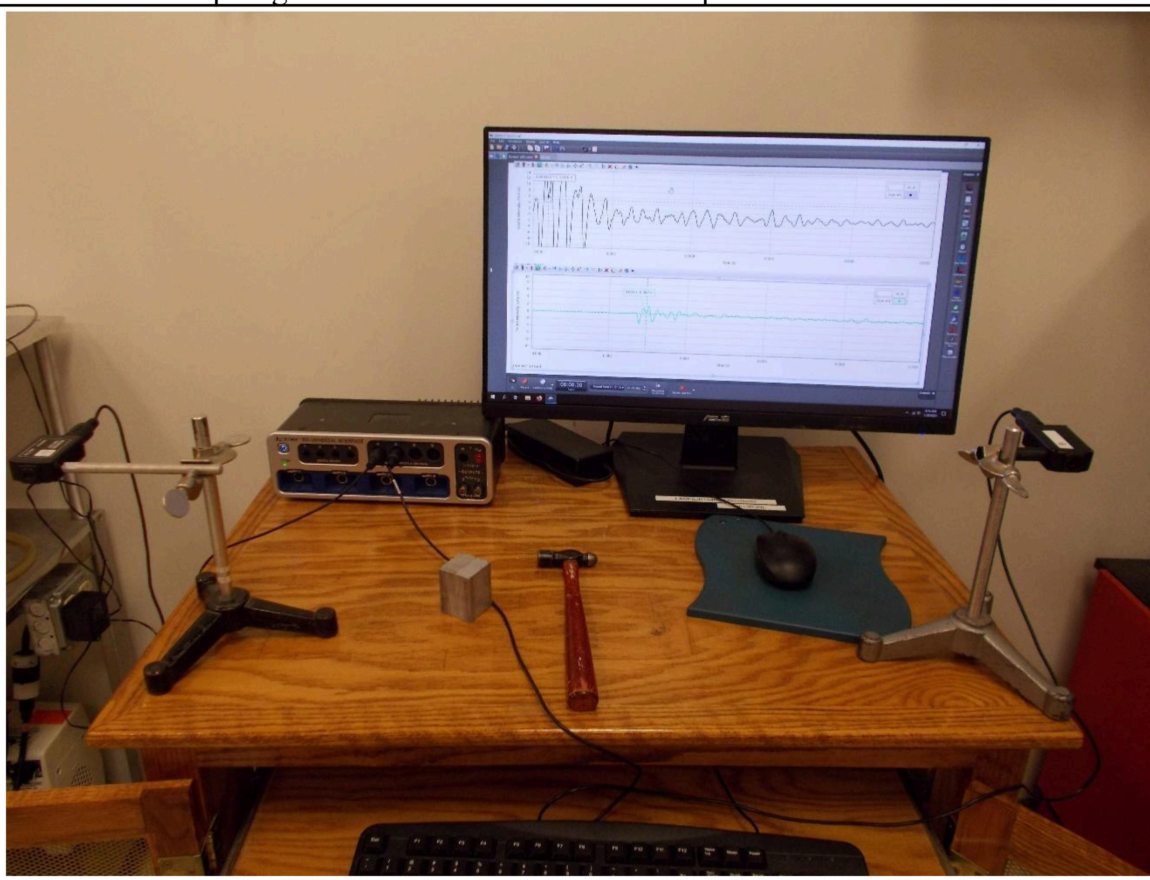
Location: Ec5

OSCILLATIONS AND WAVES	3B30.20	WAVE MOTION

Wave Properties of Sound

Direct Measurement of the Speed of Sound

A Computer is connected to two microphones. Use the Capstone file "Speed of Sound.cap". The display shows the output of the two microphones vs. time. Click on the record button. A hammer is used to strike a metal block to create a sharp sound pulse which starts the timing and the computer displays intensity vs. time for both microphones The difference in arrival time is measured between the two microphones and using the distance between them the speed of sound can be calculated.

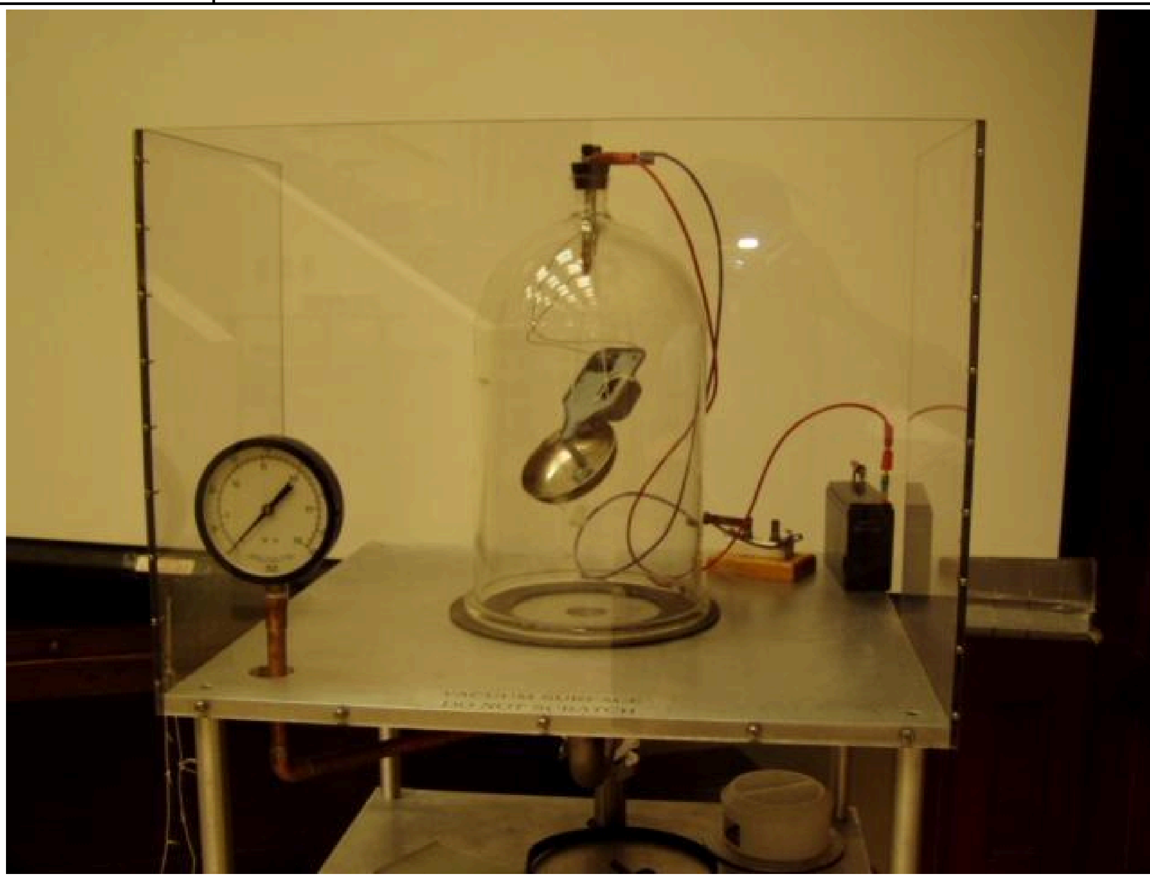


Location: Ed5, Fb5

OSCILLATIONS AND WAVES	3B30.30	WAVE MOTION
Wave Properties of Sound		

Bell in a Vacuum

	Evacuate a bell jar while a bell suspended inside is ringing. This demonstration is a bit more complicated than it might seem: the impedance at the vacuum-glass-air interface is the reason most of the sound is reflected back into the bell jar.



Location: Ec6

OSCILLATIONS AND WAVES	3B30.50	WAVE MOTION
Wave Properties of Sound		

Helium Talking

	Sing laugh or talk while breathing helium.

Location: Ec6

OSCILLATIONS AND WAVES	3B30.55	WAVE MOTION

Wave Properties of Sound

Temperature and the Speed of Sound

Liquid Nitrogen is poured down a sounding organ pipe. The pitch drops and then rises again as the temperature goes back up.

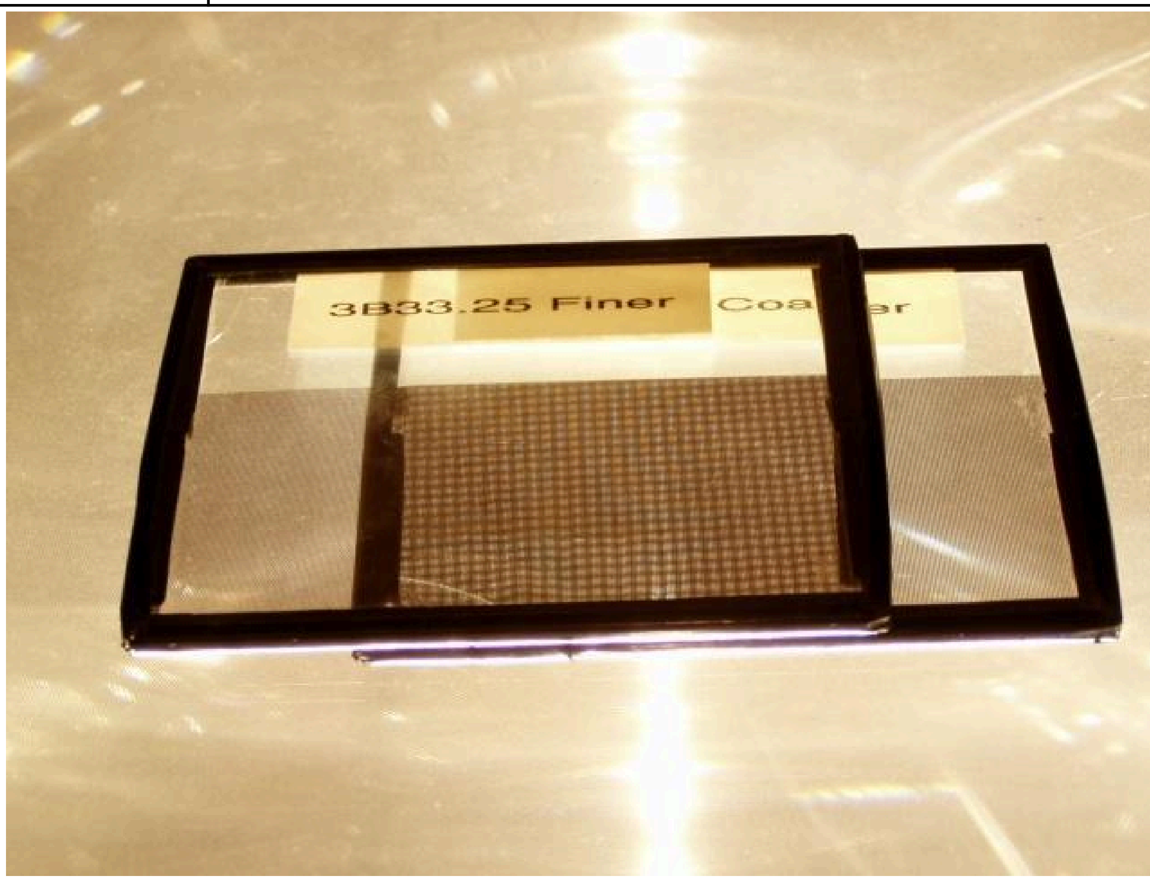
Location: Fa4

OSCILLATIONS AND WAVES	3B33.25	WAVE MOTION

Phase and Group Velocity

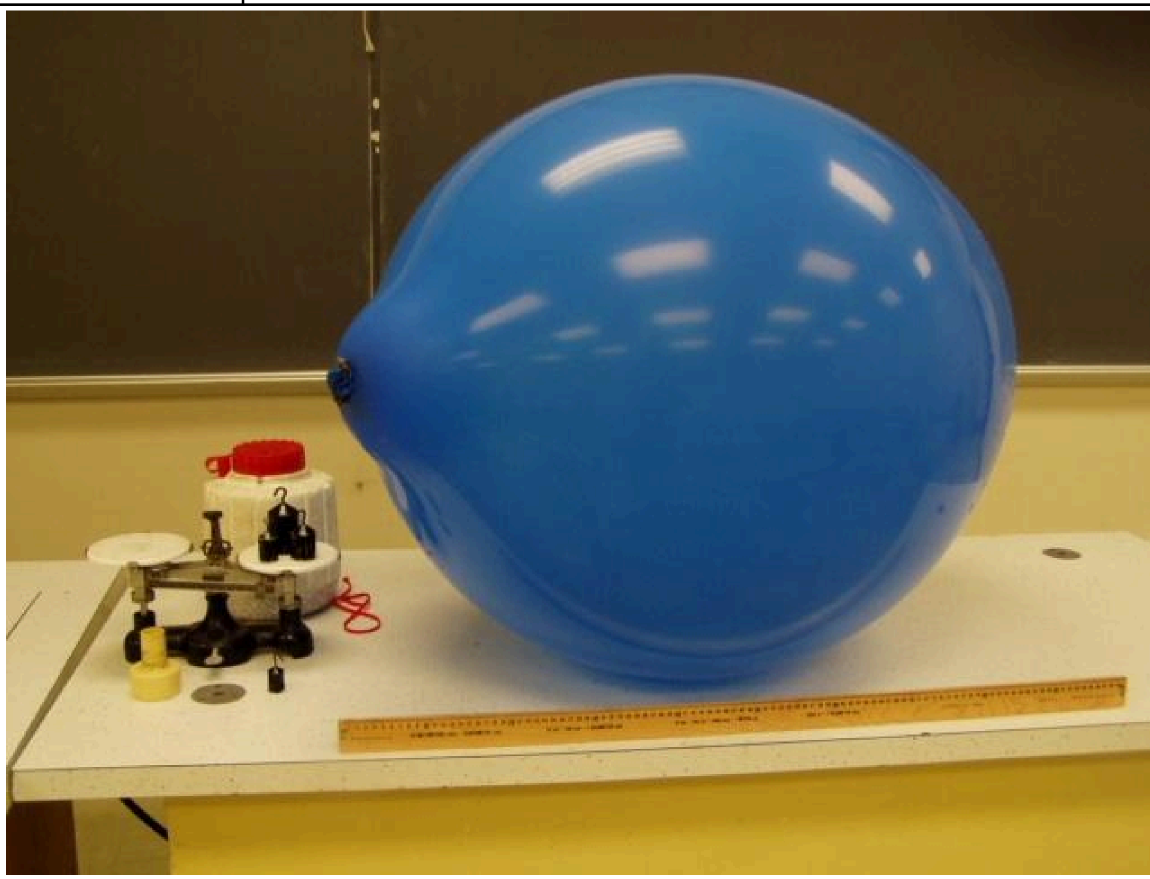
Phase and Group Velocity on the OHP

Two slides with pieces of wire mesh of slightly different spacing are laid on top of one another on the Overhead projector. A Moire pattern is seen and when the slides are moved as one, the pattern moves at the same speed and direction. The phase and group velocity are the same. If the slide with the finer spacing is moved slightly faster than the one with the coarser spacing, the pattern (wave groups) can be seen to move faster than either slide and the group velocity is greater than the phase velocity.



Location: Ec5

OSCILLATIONS AND WAVES	3B35.10	WAVE MOTION
	Reflection and Refraction (Sound)	
	Gas Lens	
	Inflate 3 foot diameter weather balloon with CO_2 (use about 0.8 kg of dry ice; it takes about an hour to sublime). The slower sound speed in CO_2 causes the balloon to be a spherical refracting surface and it behaves like a lens for sound with a focal length of about 4/3 R.	



Location: Gb1, (Dry Ice is in Hamilton Hall 701)

OSCILLATIONS AND WAVES	3B35.30	WAVE MOTION
Reflection and Refraction (Sound)		

Curved Reflectors

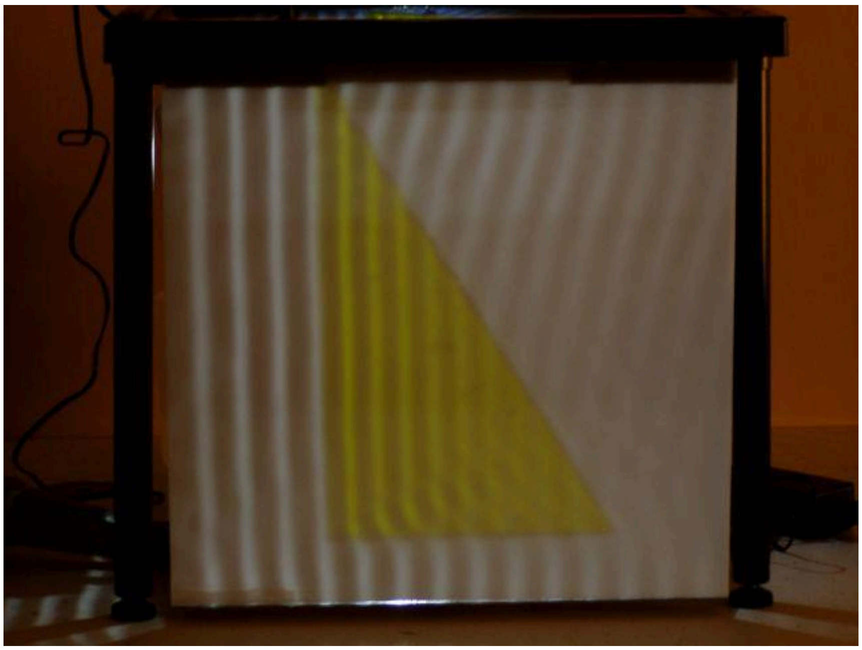
	Place a radio at the focus of a large paraboloid and beam the sound around the room. A second reflector can be used as a receiver.

Location: EaT, GaT

OSCILLATIONS AND WAVES	3B35.60	WAVE MOTION
Reflection and Refraction (Sound)		

Refraction of Water Waves

	Plane waves refract in a tank with deep and shallow sections. Shoals of various shapes are used to make the shallow regions.



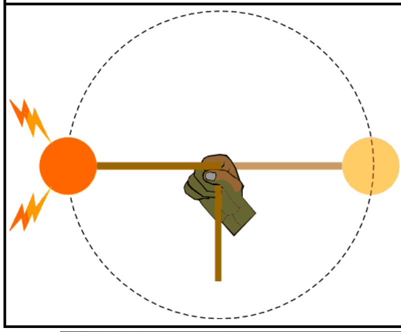
Location: Fb4

OSCILLATIONS AND WAVES	3B40.10	WAVE MOTION

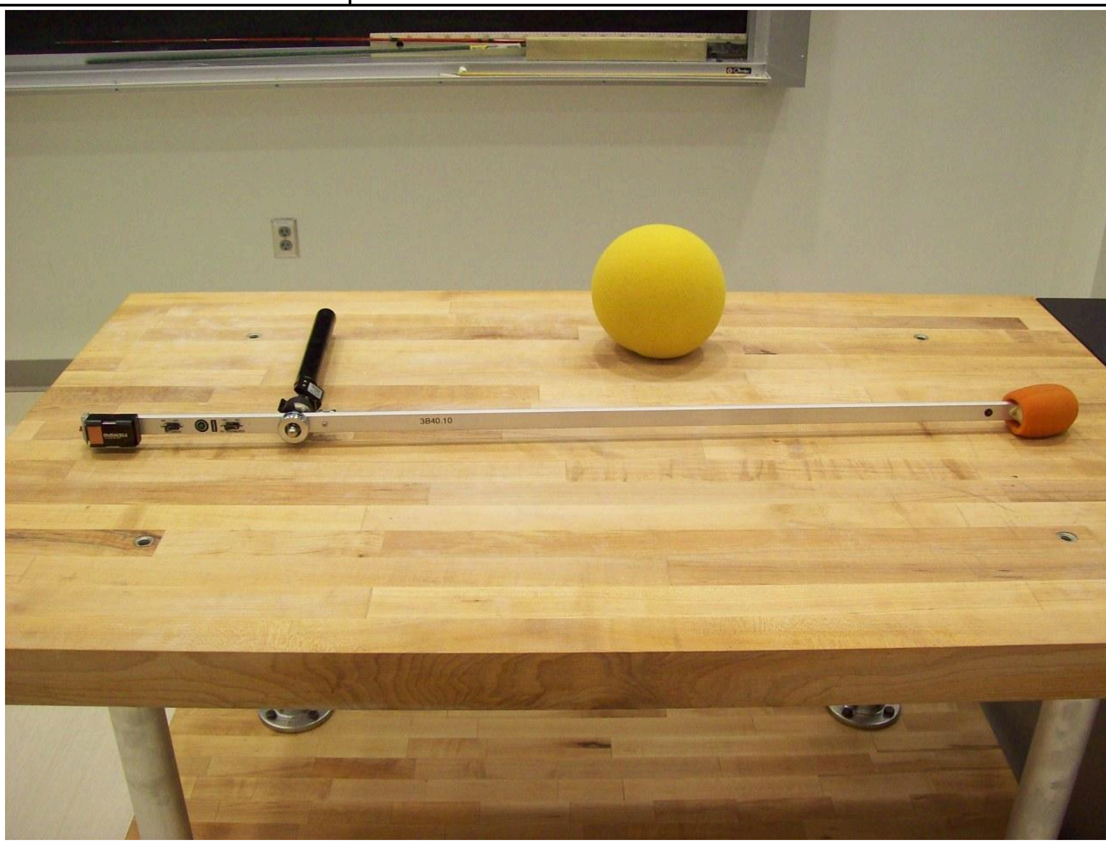
Doppler Effect

Doppler Buzzer

Disc 10-21



A buzzer and battery are tied to the end of a long string. Start the buzzer and whirl it in a horizontal circle over your head. Point out the differences in sounds between the moving and stationary buzzer. Two versions are shown in the photograph.



Location: Ec6

OSCILLATIONS AND WAVES	3B40.13	WAVE MOTION

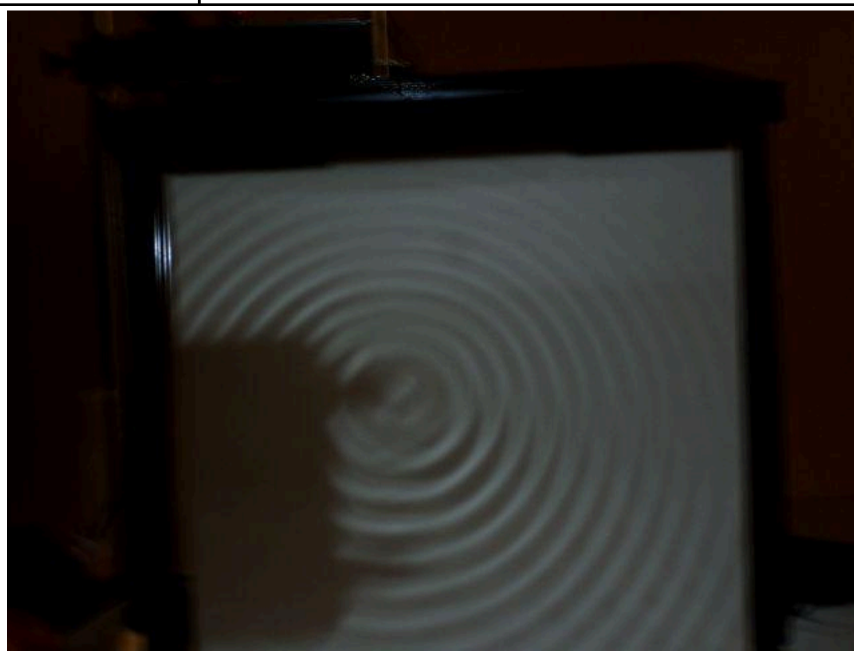
Doppler Effect

Intermittent Doppler Speaker

	A rotating speaker is switched on and off so that sound is only emitted when the speaker is moving towards or away from the audience.

Location: Ec6

OSCILLATIONS AND WAVES	3B45.15	WAVE MOTION
Shock Waves		
Doppler Effect/Shock Wave in Ripple Tank		
	Use moving point source to show Doppler effect. Move it faster to get a shockwave.	

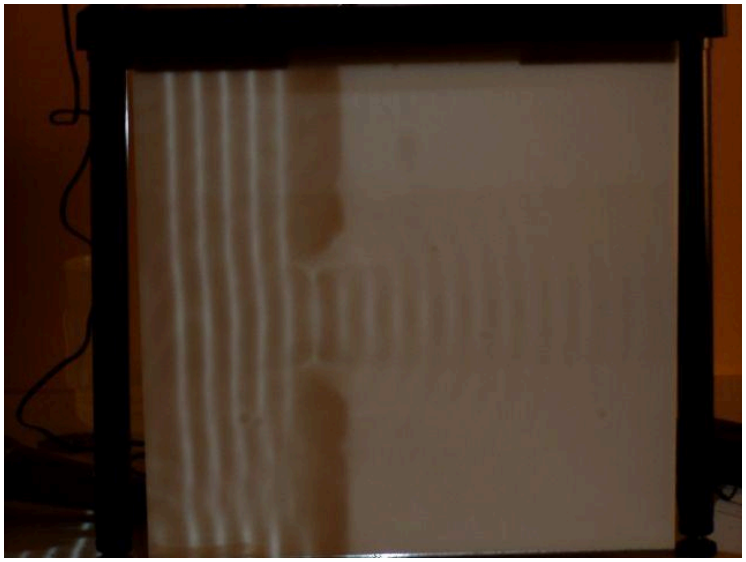


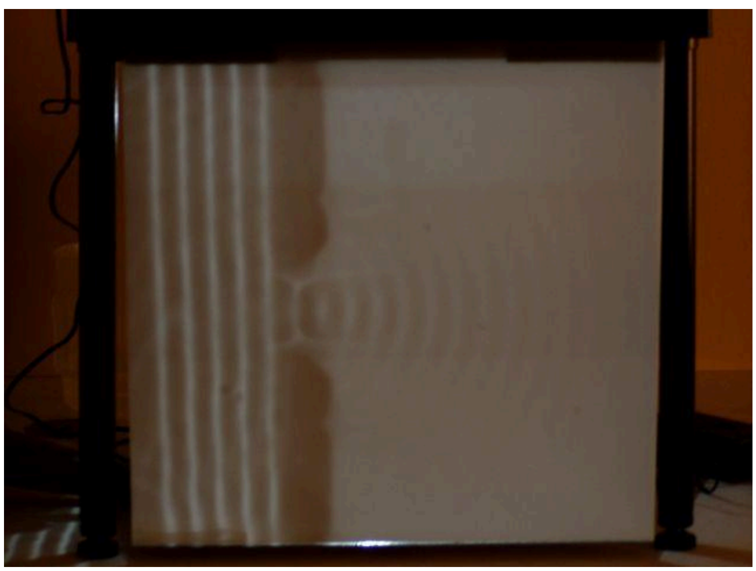
Location: Fb4

OSCILLATIONS AND WAVES	3B45.61	WAVE MOTION
Shock Waves		
Bull Whip Sonic Boom		
	The crack of a whip is caused by the tip exceeding the speed of sound.	

Location: Ec5

OSCILLATIONS AND WAVES	3B50.10	WAVE MOTION
Interference and Diffraction		
Ripple Tank – Single Slit		
	Diffraction from a plane wave passing through a single slit.	



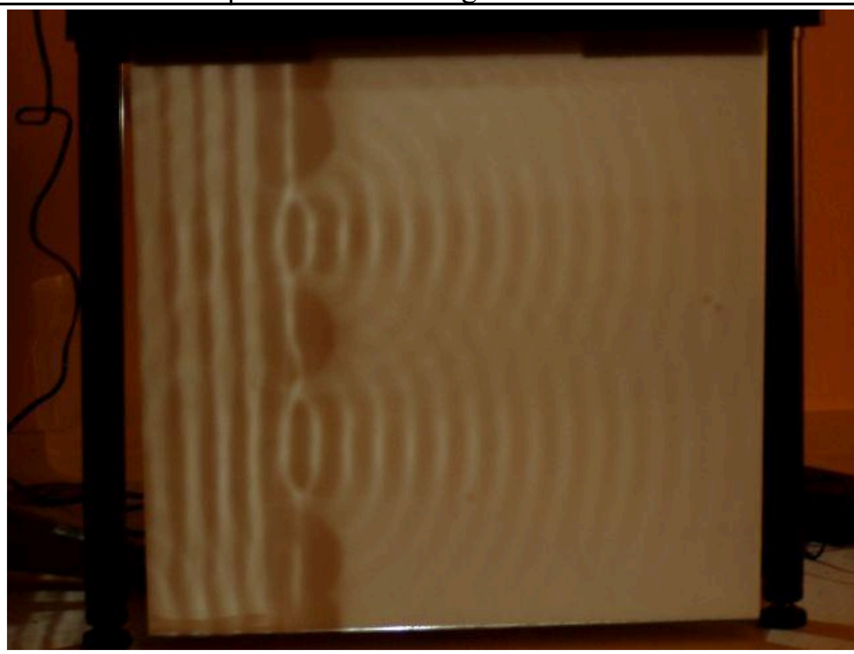


Location: Fb4

OSCILLATIONS AND WAVES	3B50.20	WAVE MOTION
Interference and Diffraction		
Ripple Tank – Double Source		
	Two point sources show interference.	

Location: Fb4

OSCILLATIONS AND WAVES	3B50.25	WAVE MOTION
Interference and Diffraction		
Ripple Tank – Double Slit		
	Plain waves through two slits show interference.	



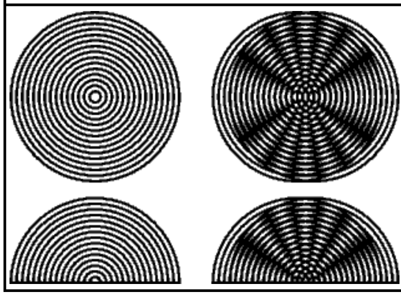
Location: Fb4

OSCILLATIONS AND WAVES	3B50.40	WAVE MOTION

Interference and Diffraction

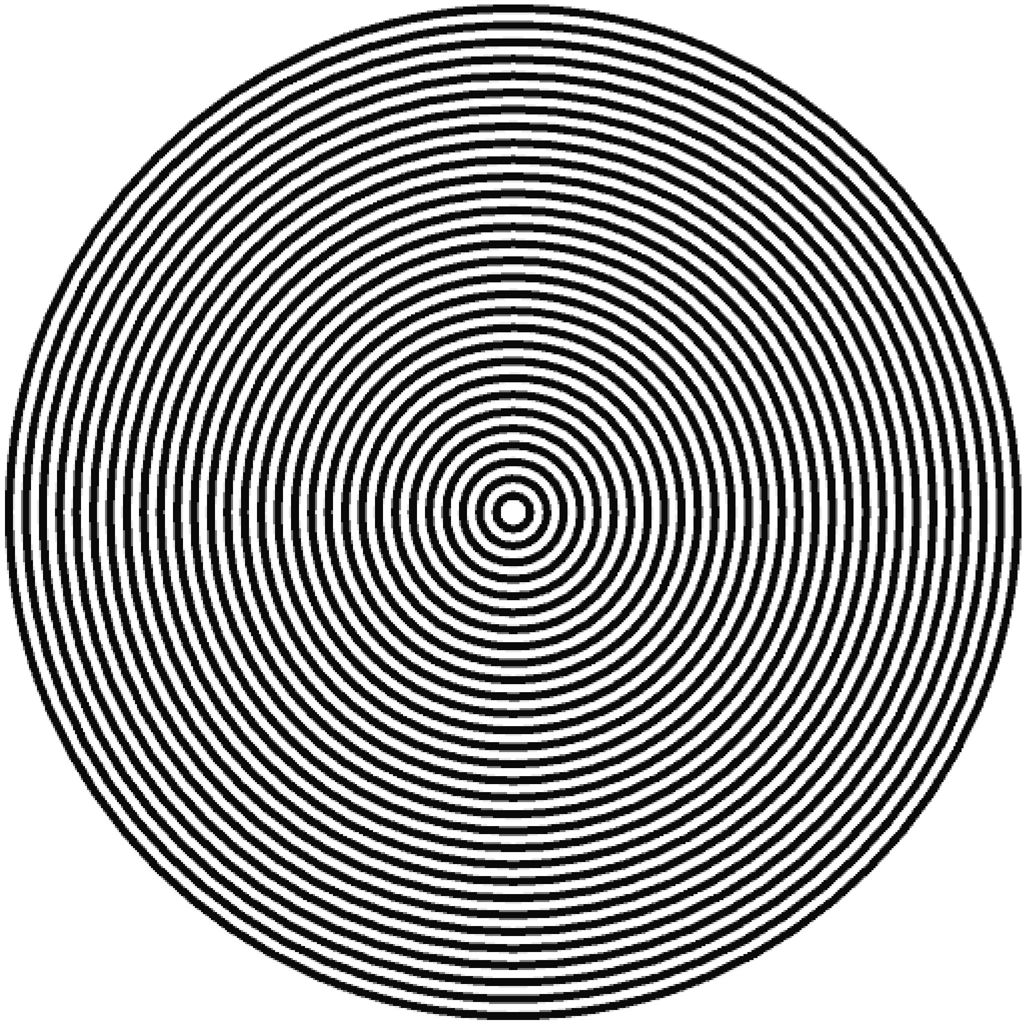
Moiré Pattern Transparencies

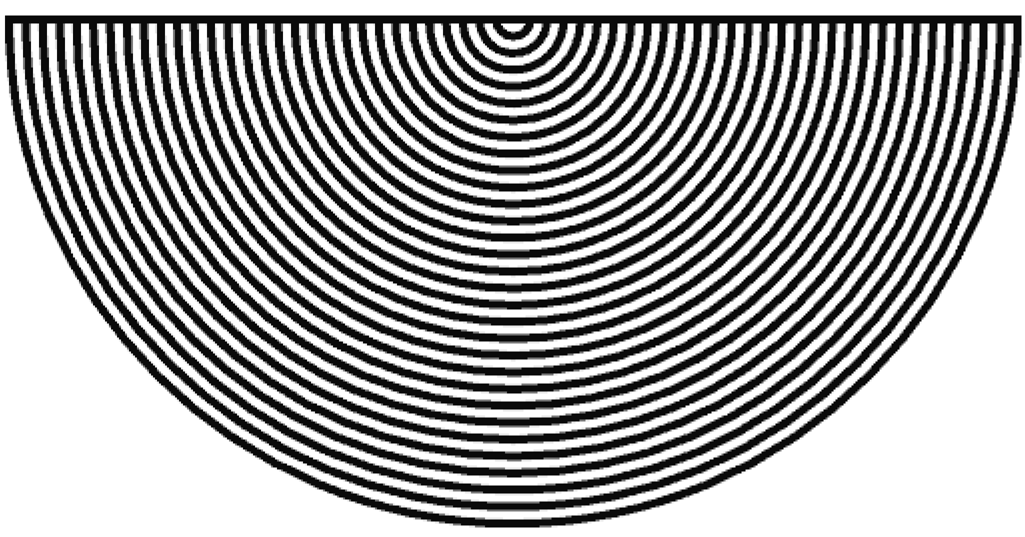
Disc 09-23



Pairs of identical transparencies have circular wave patterns of different wavelengths. Place transparencies on the overheard projector. Vary their relative positions to produce different interference patterns. Sliding wire meshes can be used to illustrate group and phase velocity.

Location: Ec5



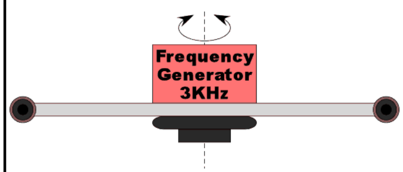


OSCILLATIONS AND WAVES	3B55.10	WAVE MOTION

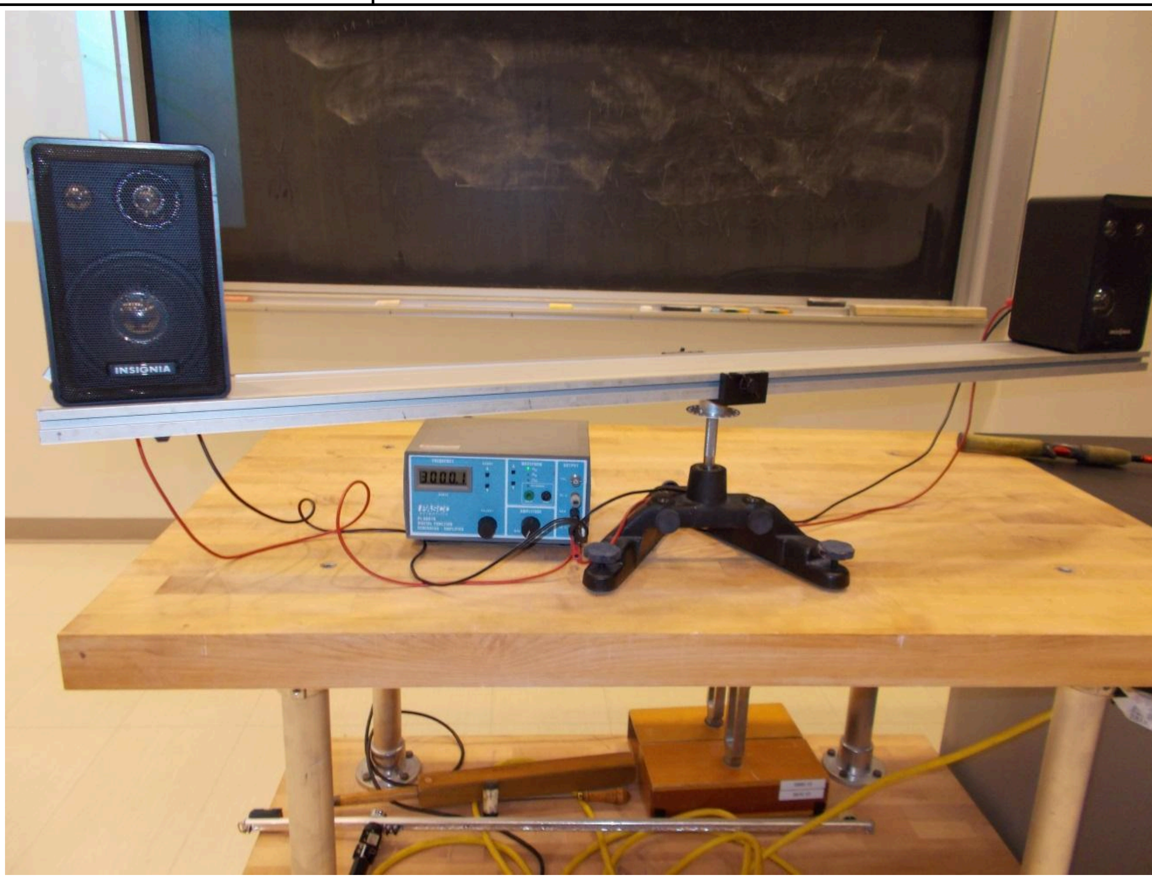
Interference of Sound

Speaker Bar

Disc 10-20



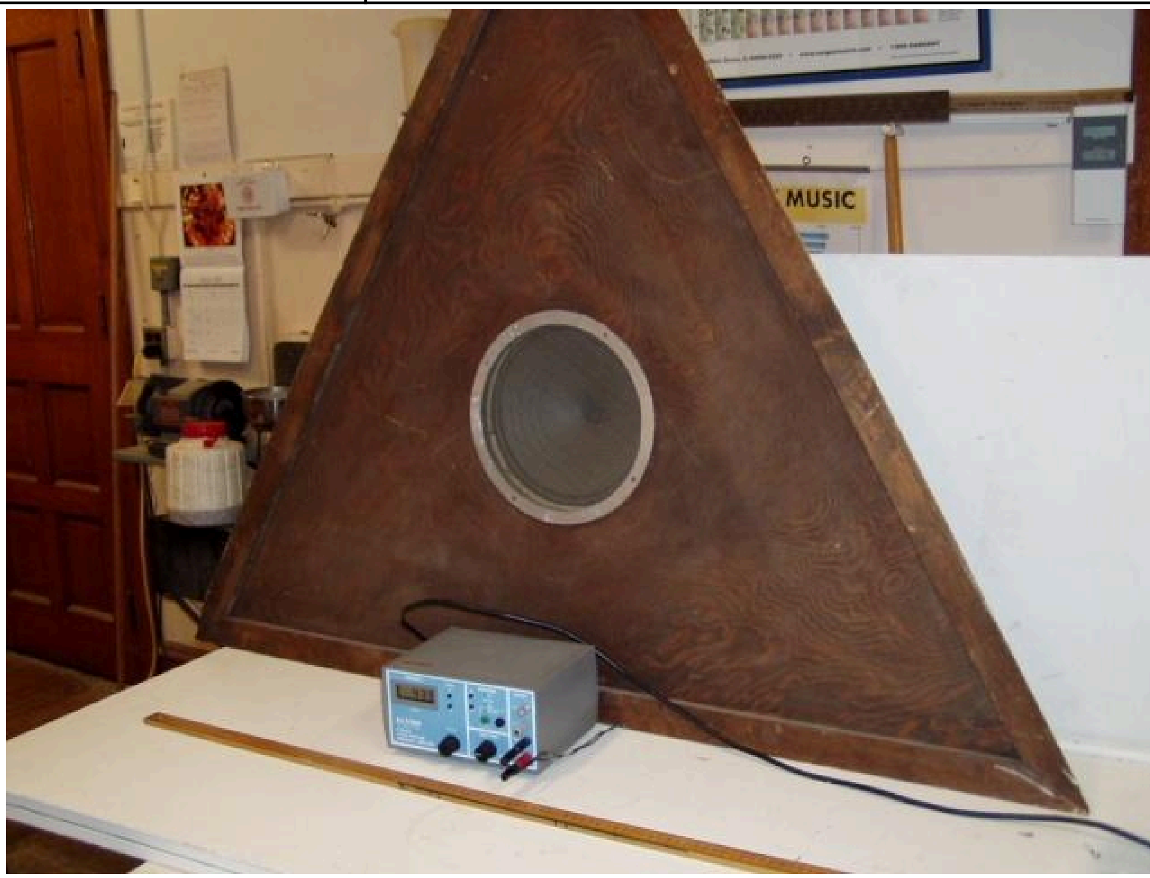
A variable function generator drives two speakers which are mounted on the ends of a long bar. Set the frequency to about 3kHz. The speaker bar is on a turntable. Direct the students to plug one ear and listen for the variations in intensity while you slowly turn the turntable. Alternately, have the students move their heads back and forth while plugging one ear (the speakers do not move). Inclusion of a rheostat allows one speaker to be turned off.



Location: Fb4, Fb5

OSCILLATIONS AND WAVES	3B55.30	WAVE MOTION

Interference of Sound	
Baffle and Speaker	
	A 10 inch speaker is driven with about a 50 Hz triangular wave with and without a baffle.

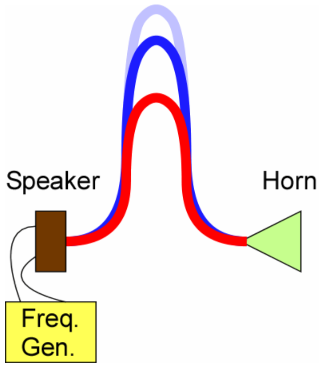


Location: Corner behind door

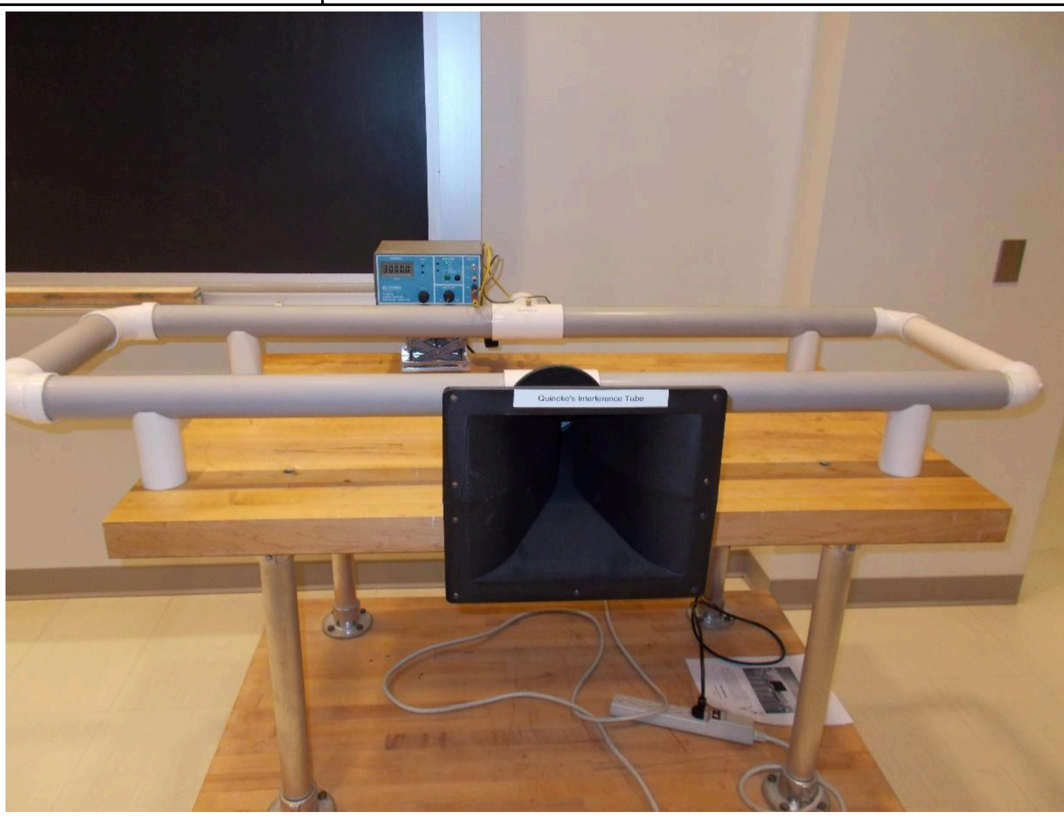
OSCILLATIONS AND WAVES	3B55.40	WAVE MOTION

Interference of Sound

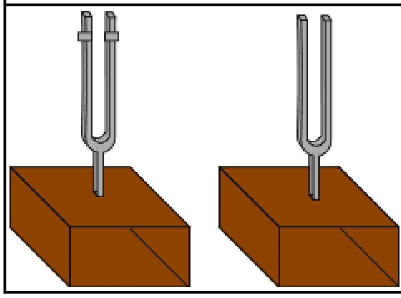
Quinckes' Tube



A function generator drives a speaker. The sound travels through two tubes which joining together at the horn. One tube is a trombone slide. Change the distance the sound travels in the sliding tube by raising or lowering the slide. The variation in intensity as the slide is moved is quite pronounced at 3kHz. Measure the change in length of the sliding tube (twice the distance moved).



Location: EdT

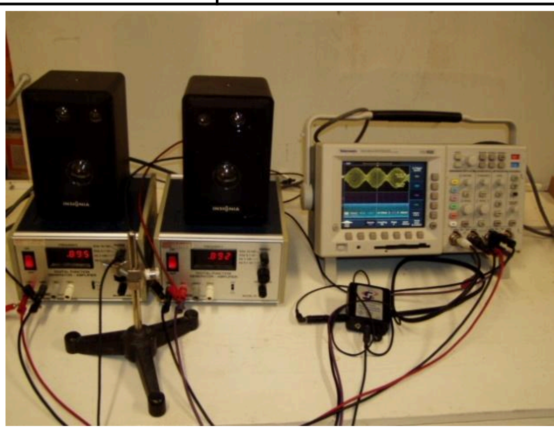
<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3B60.10</td><td>WAVE MOTION</td></tr>
<tr><td colspan="3">Beats</td></tr>
<tr><td colspan="3">Beat Forks</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Strike the tuning forks with the rubber mallet. Vary the beat frequency by adjusting the position of the small masses on the one tuning fork.</td></tr>
</table>

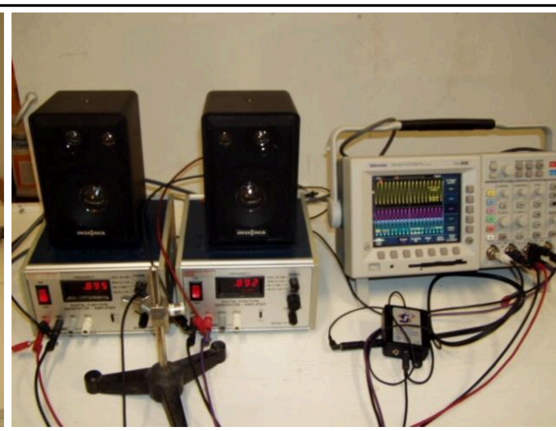
Location: Ed1

OSCILLATIONS AND WAVES	3B60.20	WAVE MOTION
	Beats	

Beats on ‘Scope

	Two oscillator/drivers are connected to speakers and adjusted so that beats are heard. The combined output is observed on an oscilloscope to which a microphone has been connected (Ch1). The individual oscillators are connected to Ch2 and Ch3. The Setup file in the oscilloscope is “Beats”, Setup 5. Adjust the sweep rate to see either the envelope or the individual oscillations.





Location: Ed5, Fb4, Fb5

OSCILLATIONS AND WAVES	3B70.10	WAVE MOTION
Coupled Resonators		

Coupled Tuning Forks

	Two tuned tuning forks are mounted on separate boxes. Hit one and the other vibrates too.

Location: Ed1

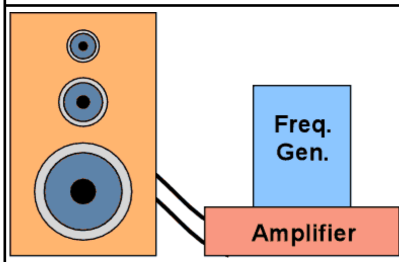
OSCILLATIONS AND WAVES	3C10.10	ACOUSTICS
The Ear		
Model of the Ear		
	An anatomical model of the ear.	

Location: Ed2

OSCILLATIONS AND WAVES	3C20.10	ACOUSTICS

Pitch

Range of Hearing



Hook a function generator to a speaker. Change the pitch as the class listens. Have the class raise their hands only as long as they can hear at the extreme ends of the hearing range. At subsonic frequencies you can see the speakers vibrate. Hearing -3dB is often shown at the same time.

Location: Ed3, Fb4

OSCILLATIONS AND WAVES	3C20.20	ACOUSTICS

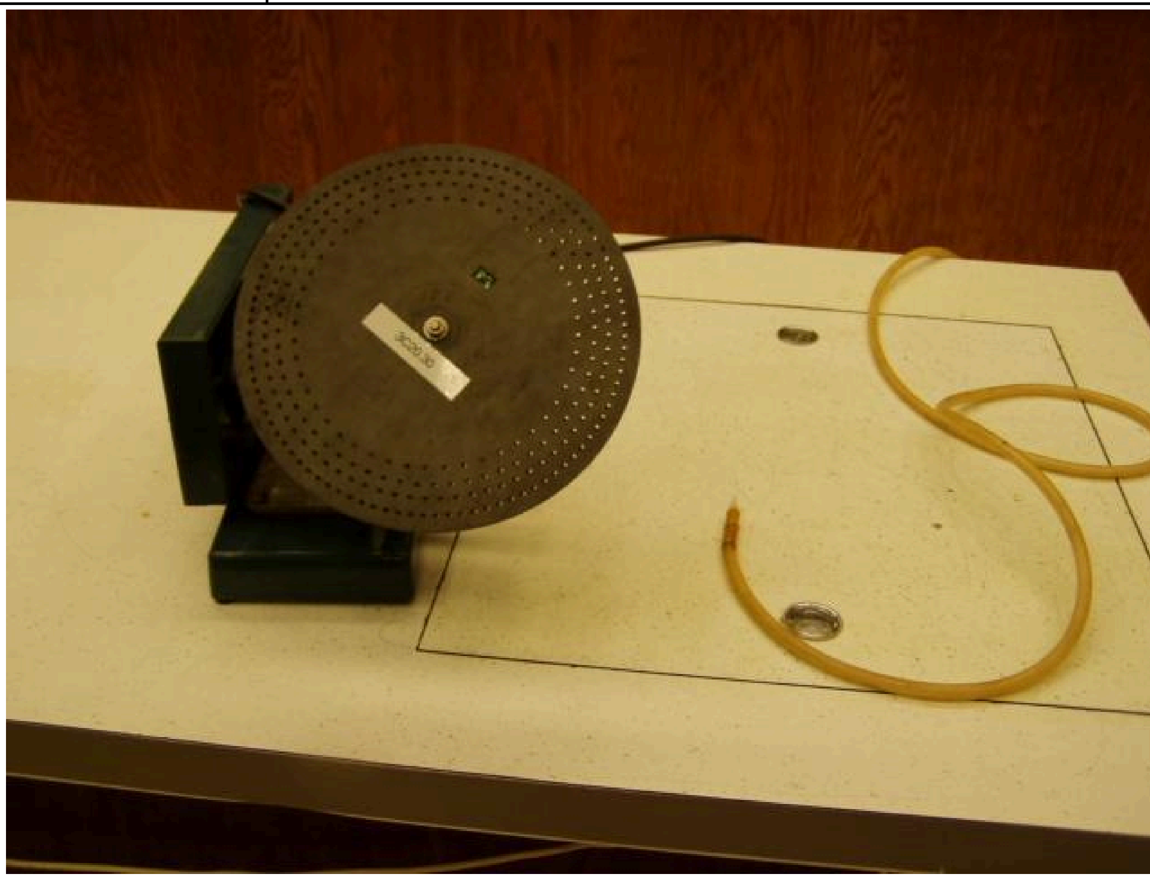
Pitch

Zip Strips

Put a knot in the top end of the zip strip and insert into the cup up to the knot. Using your fingernail on the raised ridges that are on one side of the strip, smoothly pull down the length of the strip. The strip should make a sound that is close to understandable words. Strips come with words such as "Happy Birthday", "Happy New Year", and "Science is Fun".

Location: Ed4

OSCILLATIONS AND WAVES	3C20.30	ACOUSTICS
Pitch		
Siren Disc		
	Air is blown through concentric rows of regularly spaced holes on a spinning disc. As the rotation speed changes the pitches change but not the intervals.	

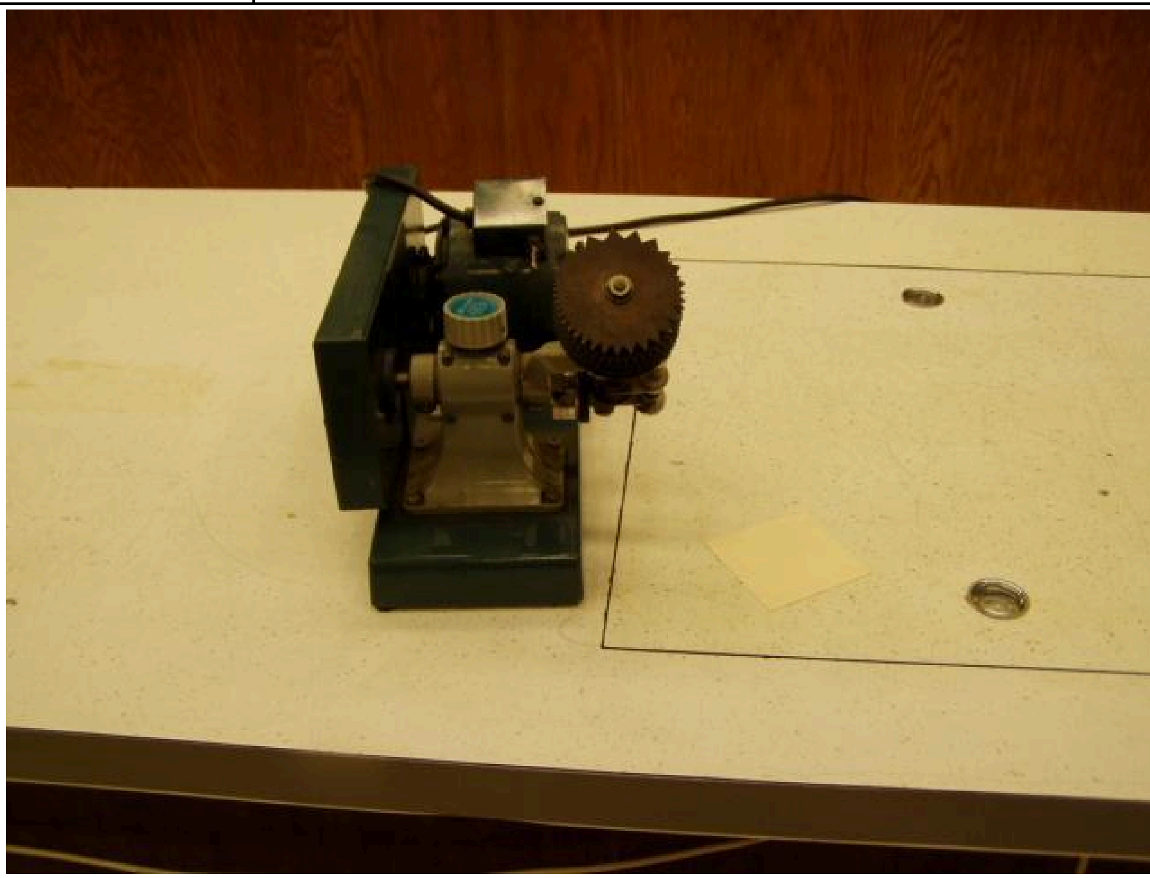


Location: Ed4

OSCILLATIONS AND WAVES	3C20.40	ACOUSTICS
	Pitch	

Savart's Wheel

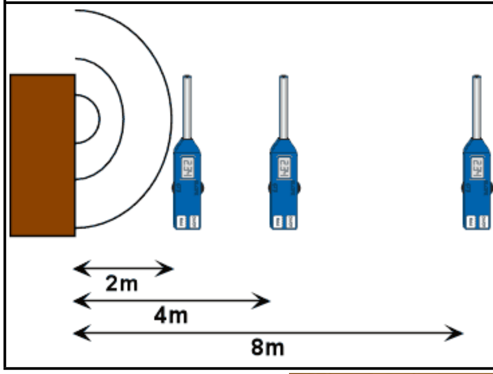
	A set of gears on the shaft of a variable speed rotator have 48, 60, 72 and 96 teeth. There is also gear with varying teeth spacing. Holt a stiff card against the teeth and listen for the pitches.



Location: Ed4

Intensity and Attenuation

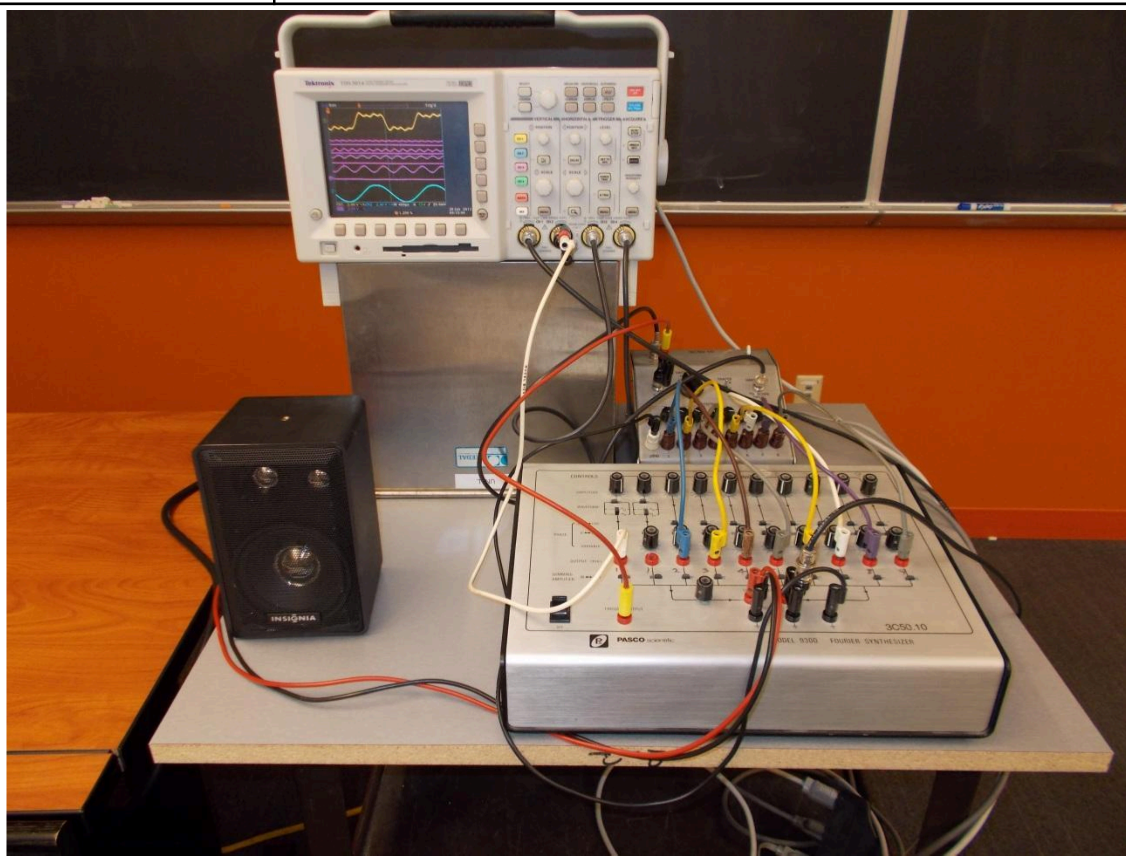
DB Meter and Speaker



Place dB meters in the class at 2 meter intervals, then blow a loud horn. We use a noise generator for an incoherent source to eliminate interference from reflections in the room.

Location: Ed5

OSCILLATIONS AND WAVES	3C50.10	ACOUSTICS
Wave Analysis and Synthesis		
Pasco Fourier Synthesizer		
	The synthesizer produces ten waves, 2 fundamentals and 8 harmonics, whose relative phases and amplitudes can be varied.	

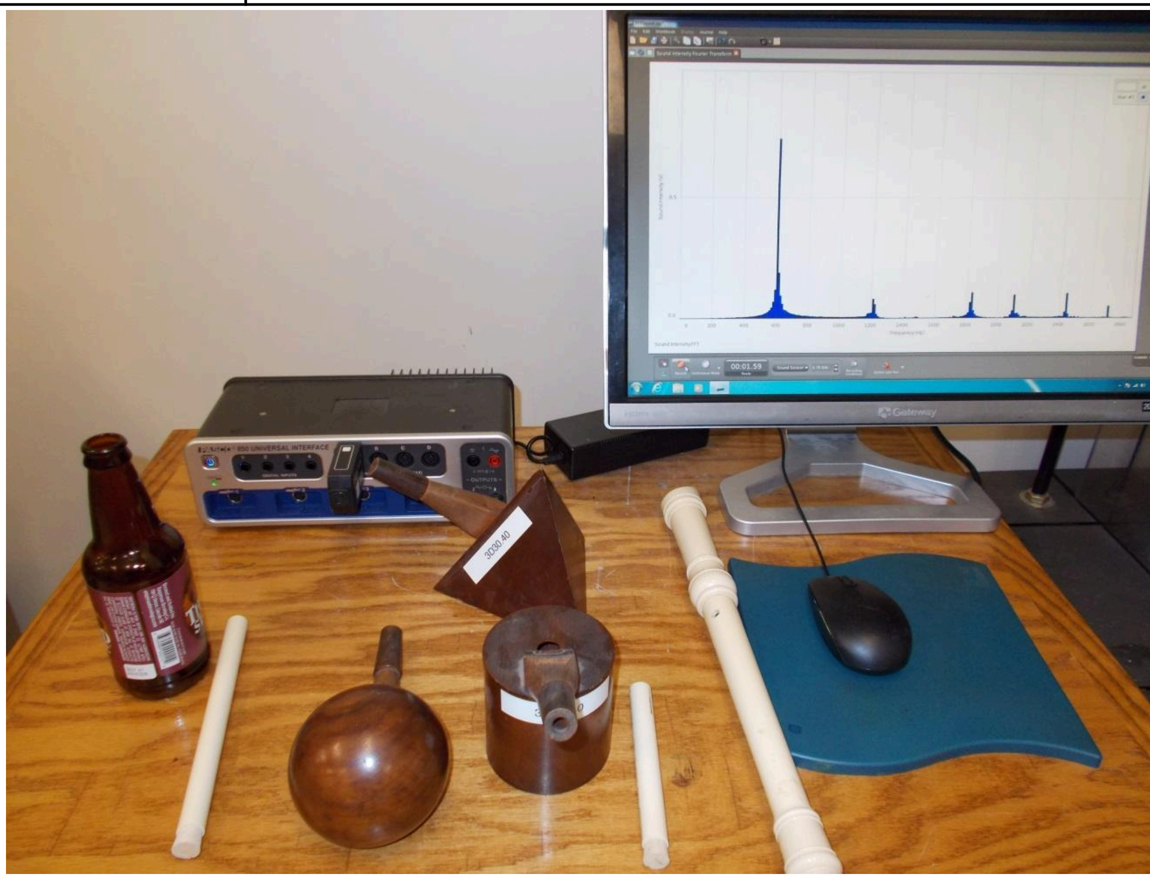


Location: Ed6

OSCILLATIONS AND WAVES	3C50.80	ACOUSTICS
Wave Analysis and Synthesis		

Spectrum Analyzer

	The Science Workshop software and a microphone are used to do a Fast Fourier Transform of various musical instruments and sounds. Shown in the photograph is the spectrum of a recorder. The Capstone file is FFT Sound.cap.



Location: Science Workshop Cabinet, Fa2, Fa3, Ed6

OSCILLATIONS AND WAVES	3C55.30	ACOUSTICS

Music Perception and the Voice

Difference Tones

	Two oscillators each connected to a speaker initially are set at aboput 880 Hz and generating square waves. One of the Oscillators is then slewed down in pitch. If you listen carefully you will here a difference tone rising in pitch.

Location: Fb4, Fb5

OSCILLATIONS AND WAVES	3C55.70	ACOUSTICS
Music Perception and the Voice		

Microphone and Oscilloscope

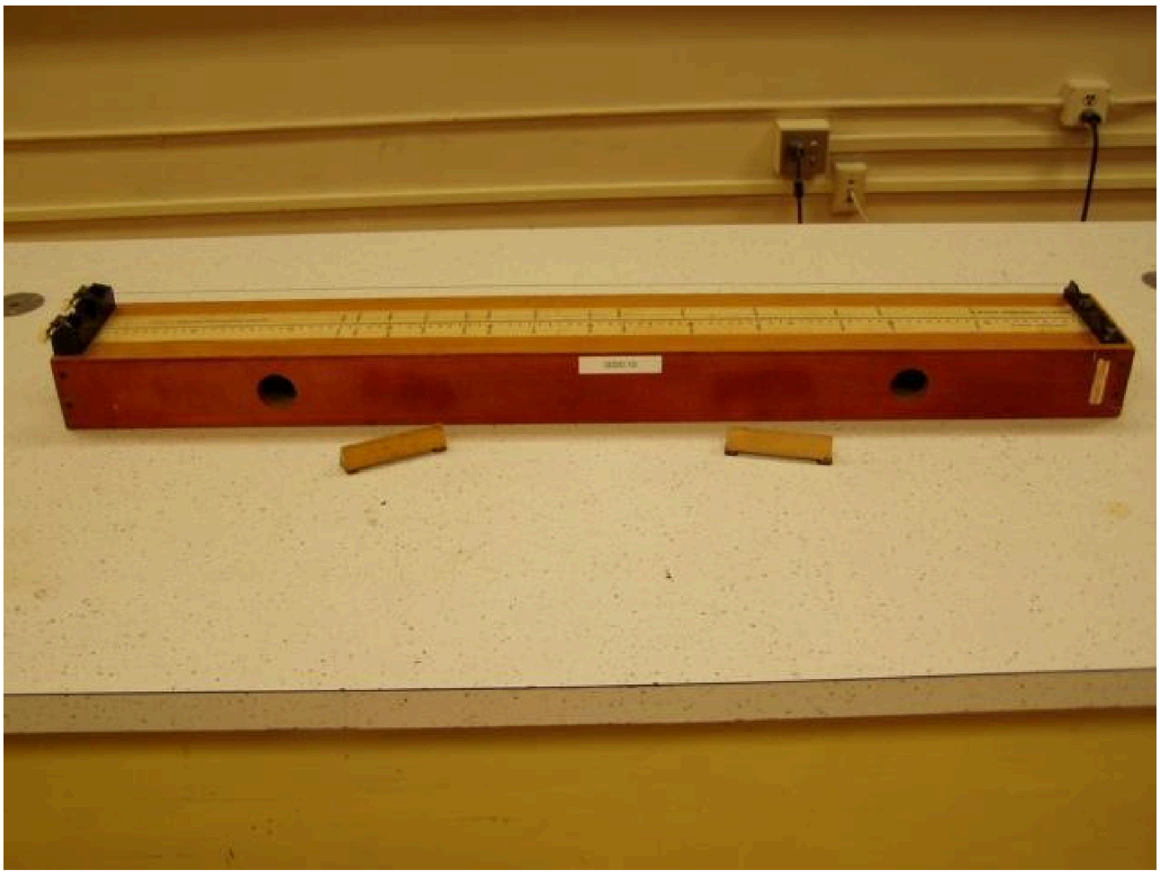
	A microphone is connected to an oscilloscope and the waveforms of various instruments and the voice are displayed

Location: Ed5, Fb5

OSCILLATIONS AND WAVES	3C55.90	ACOUSTICS
Music Perception and the Voice		
Auditory Demonstrations		
	39 auditory demonstrations on a CD	

Location: Ed6

OSCILLATIONS AND WAVES	3D20.10	INSTRUMENTS
Resonance in Strings		
Sonometer		
	A sounding box with strings bridges and machine tuning heads.	



Location: Ed7

OSCILLATIONS AND WAVES	3D20.15	INSTRUMENTS

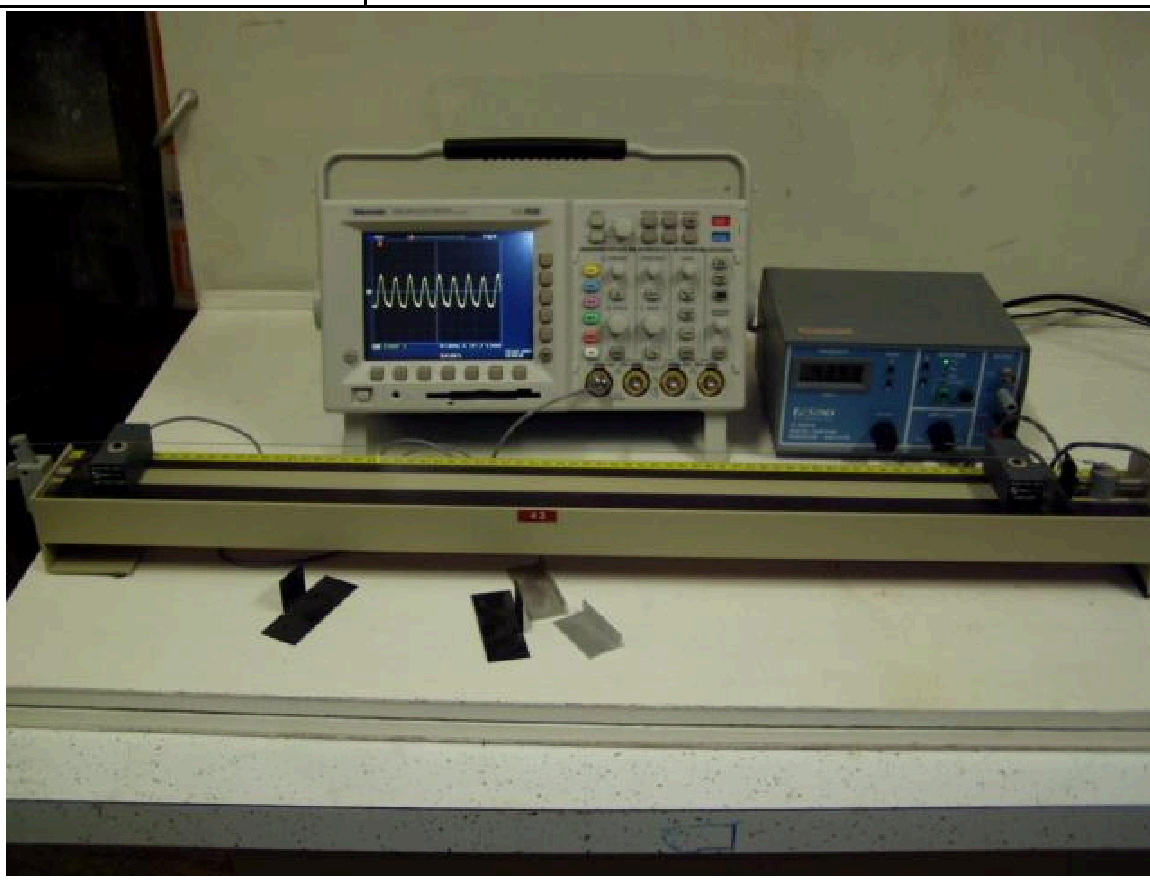
Resonance in Strings

Harmonics on a String

Pluck a string at different distances from the end or lightly touch it a node and pluck. The sonometer has a scale to help find the nodes; for the guitar, use the 12th, 7th, or 5th frets (those are the easiest ones; for the violin: bow near the bridge while lightly touching the string at a node.

Location: Ed7, Ed8

OSCILLATIONS AND WAVES	3D20.20	INSTRUMENTS
Resonance in Strings		
Modes of a String		
	A sonometer is monitored with a guitar pickup connected to an oscilloscope. An electromagnetic driver is connected to an oscillator. The string tension and length can be adjusted. The string can be driven in its various modes as well as with a square wave.	



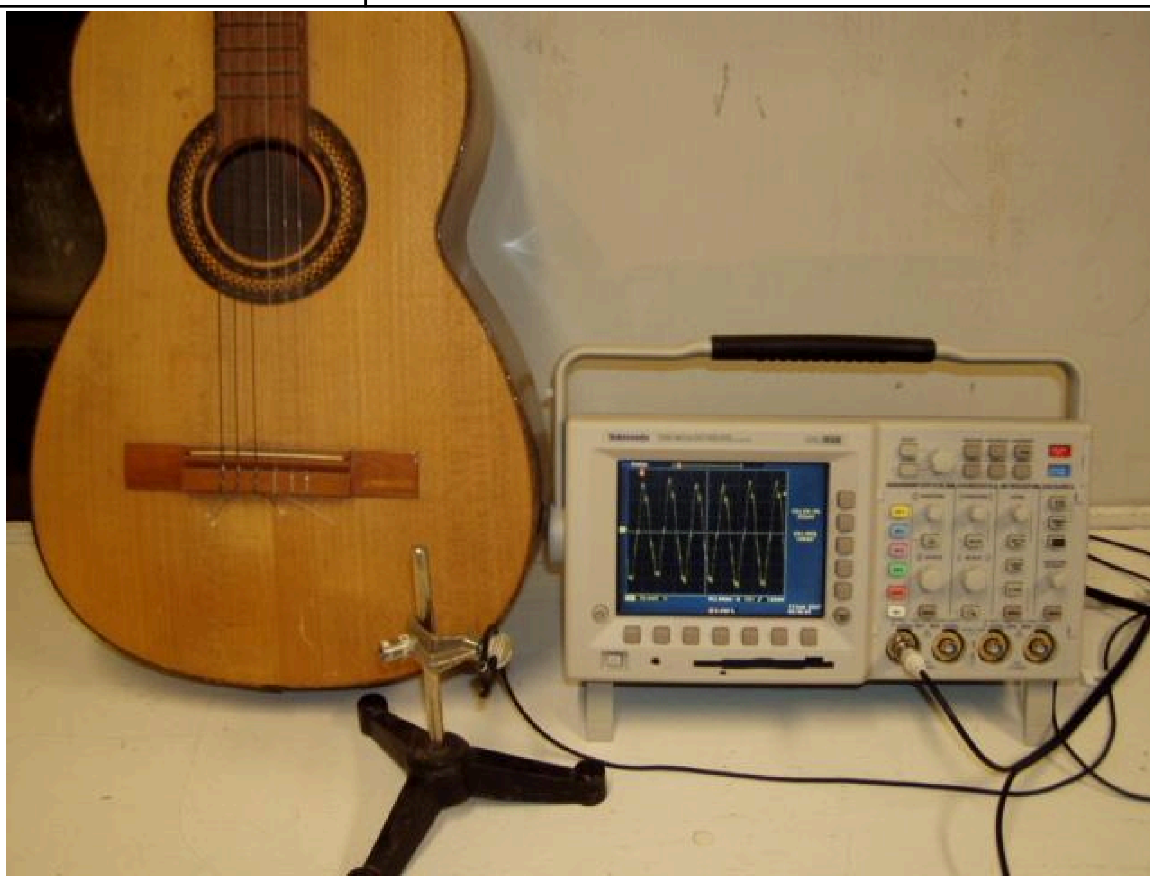
Location: Ed7, Fb4, Fb5

OSCILLATIONS AND WAVES	3D20.21	INSTRUMENTS

Resonance in Strings

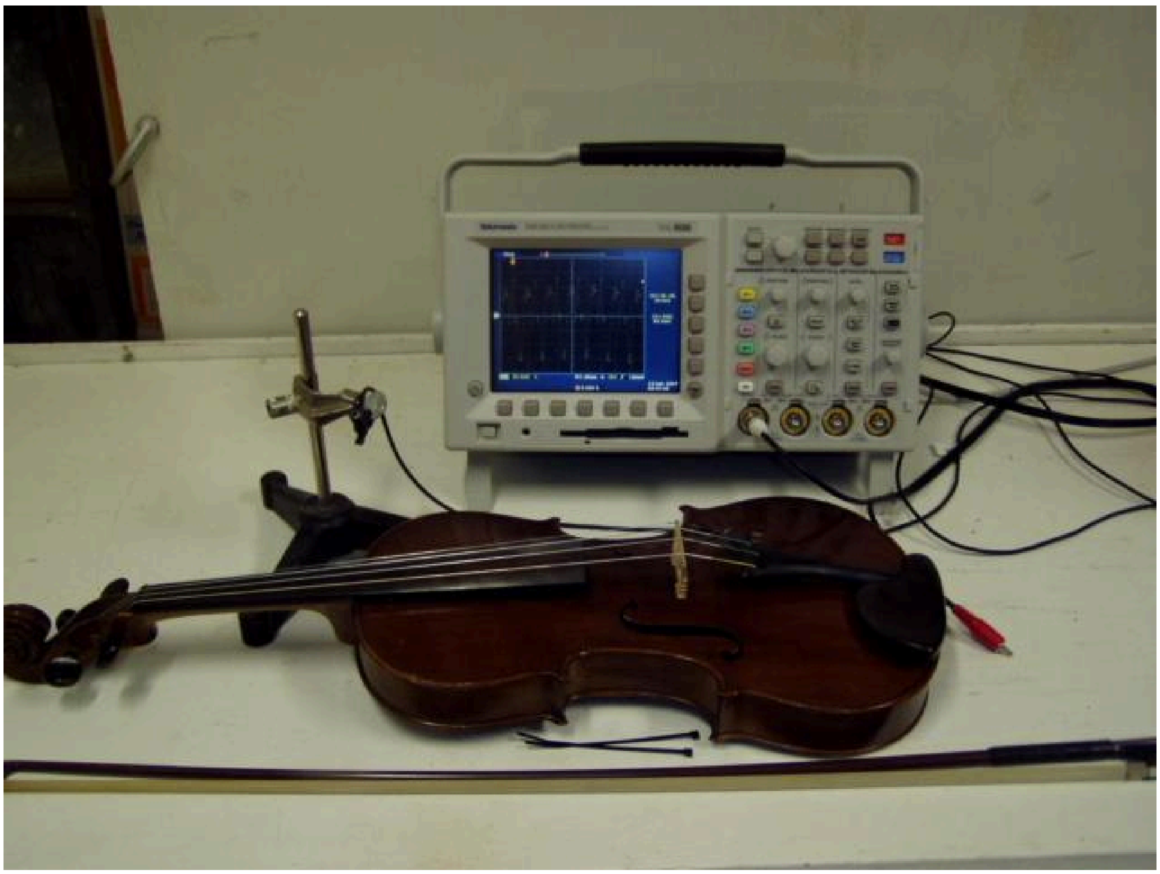
Guitar and 'Scope

Show the sounds produce by plucking a guitar on the oscilloscope. Use the Setup Microphones and turn off Ch2. It is helpful to use the single trace mode either triggered by the pluck or manually started after the pluck. One can also use the Science Workshop Spectrum Analyzer (3C50.80).



Location: Ed8, Fb5

OSCILLATIONS AND WAVES	3D22.10	INSTRUMENTS
Stringed Instruments		
Violin		
	Show the violin’s sound on an oscilloscope; One can also use the Science Workshop Spectrum Analyzer (3C50.80).	

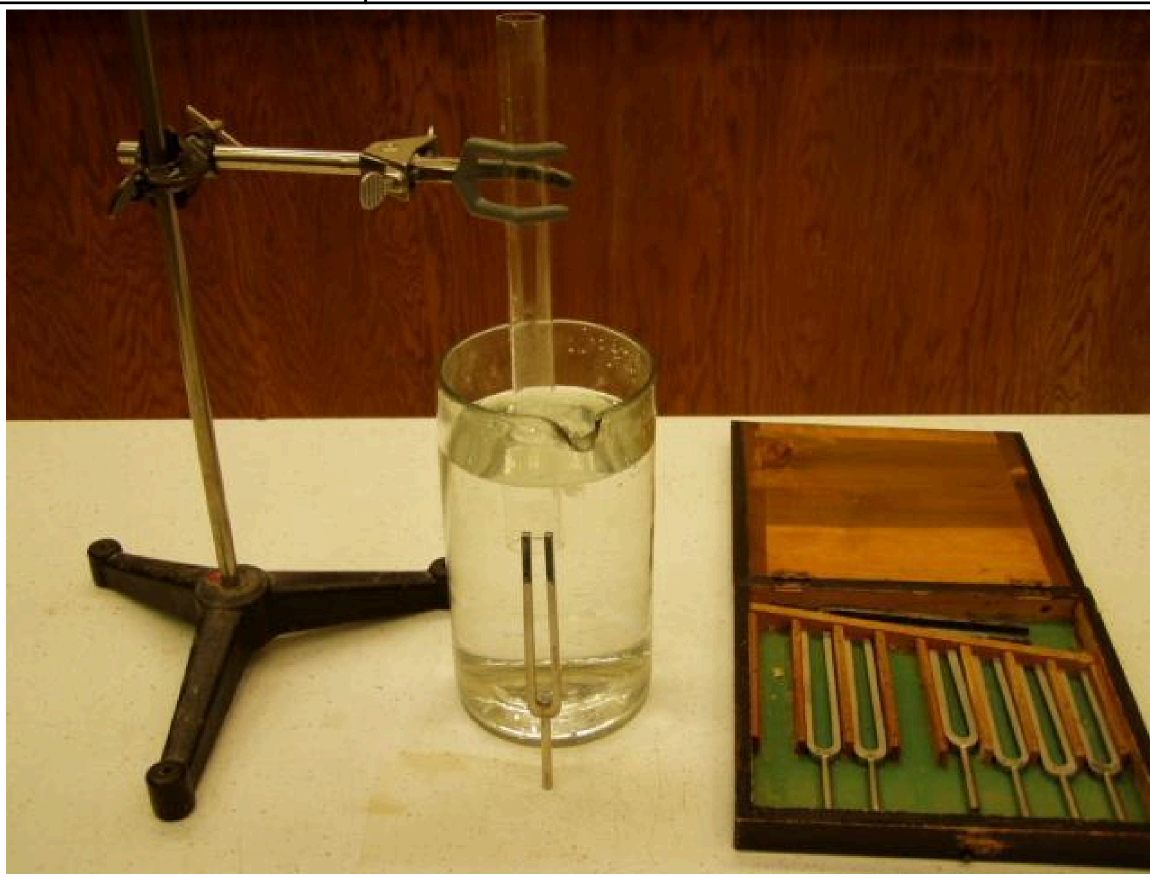


Location: Ed8, Fb5

OSCILLATIONS AND WAVES	3D30.10	INSTRUMENTS
	Resonant Cavities	

Vertical Resonance Tube

	Draw a glass tube out of a water bath while holding a vibrating tuning fork over one end.



Location: Fa1

OSCILLATIONS AND WAVES	3D30.15	INSTRUMENTS
Resonance Cavities		

Resonance Tube with Microphone

	A Vertical pipe closed at one end is placed on the floor. A loud speaker and oscillator is placed a meter or so away (to prevent overdriving) and tuned to one of the resonances of the pipe. The nodes are then found using a microphone connected to an oscilloscope. Use Capstone file "Resonance in a Tube"

Location: Ed5, Fb4, Fb5, Fd1

OSCILLATIONS AND WAVES	3D30.20	INSTRUMENTS

Resonance Cavities

Resonance Tubes

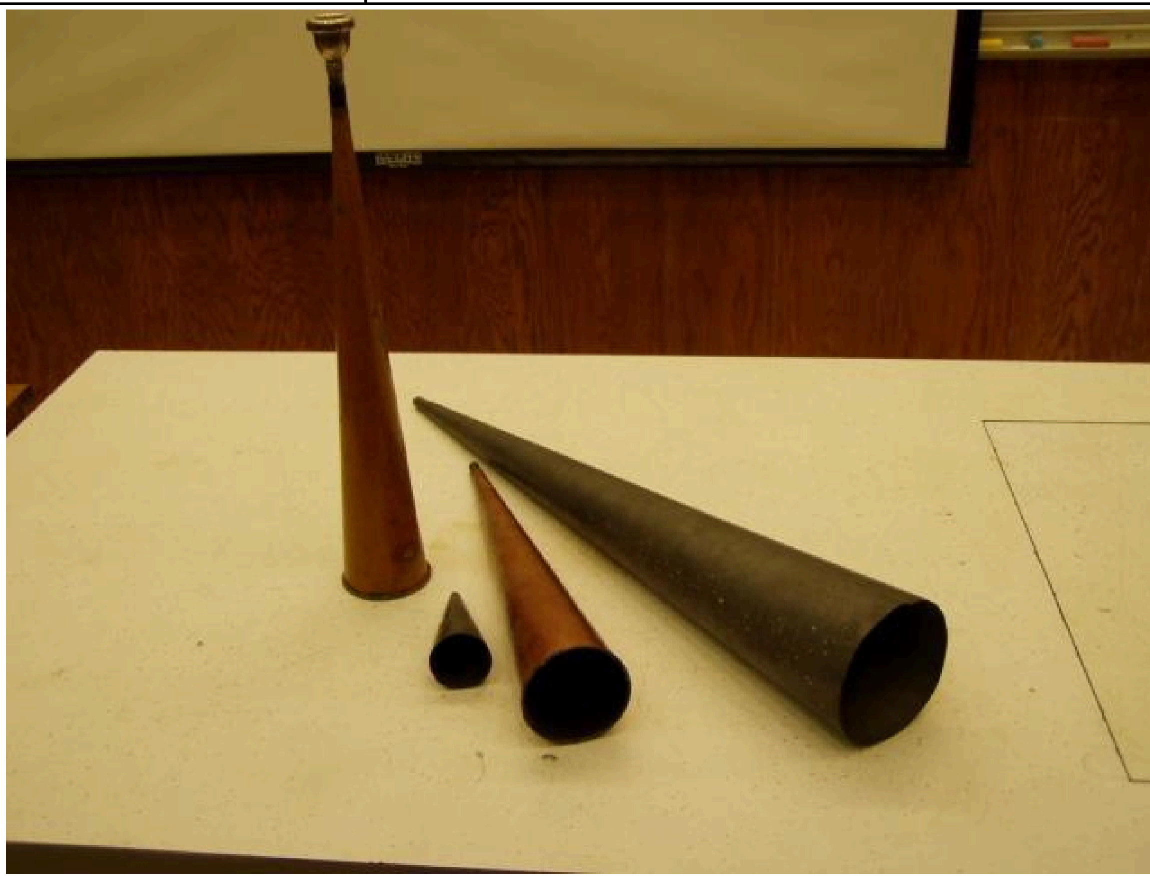
Plastic tubes of various lengths can be made to sound the notes of the scale by hitting your head (or some other, convenient soft surface) with them. There are also end caps that can close one end dropping the pitch an octave.

Location: Fa2

OSCILLATIONS AND WAVES	3D30.21	INSTRUMENTS
Resonance Cavities		

Conical Pipes

	See Sutton S-114 for several demonstrations. Bugle calls can be blown on the large one. Sutton gives corrections for the effective length and discusses where the nodes are.

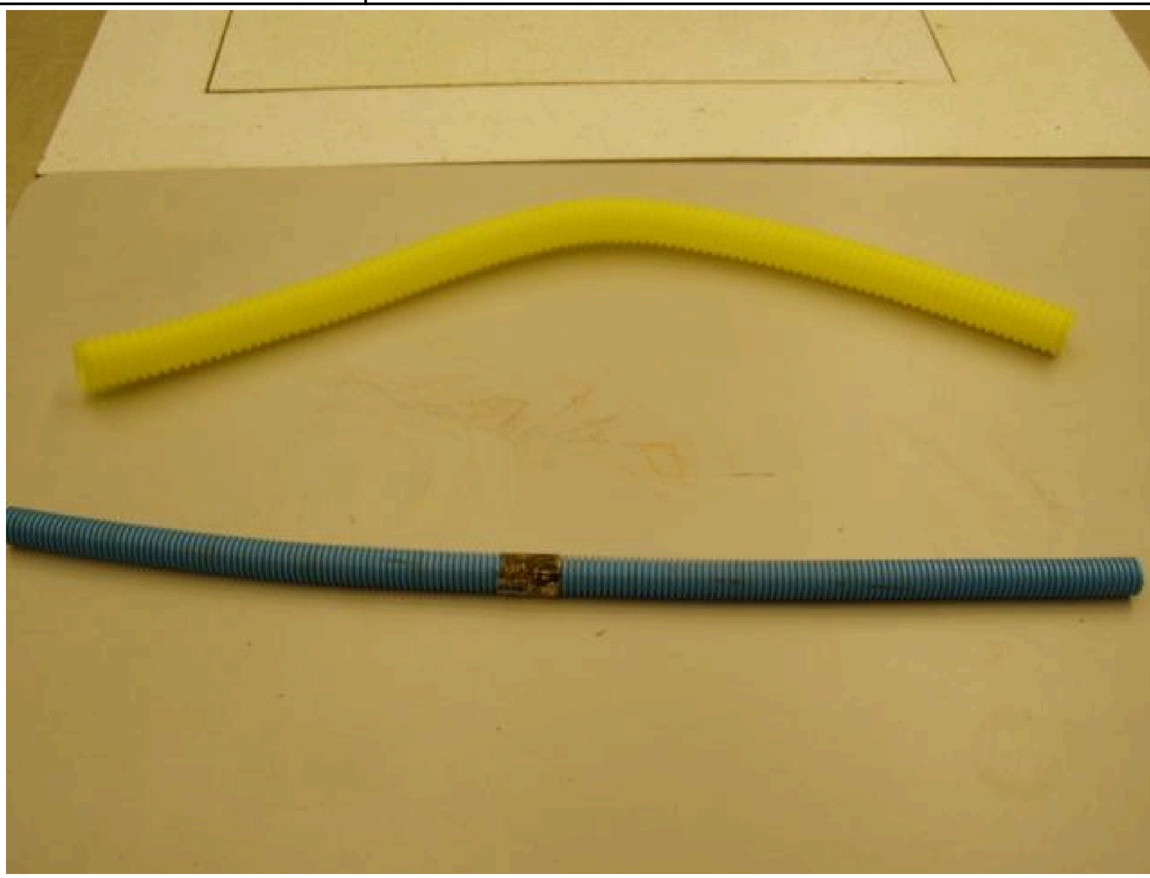


Location: Fa2

OSCILLATIONS AND WAVES	3D30.35	INSTRUMENTS
Resonance Cavities		

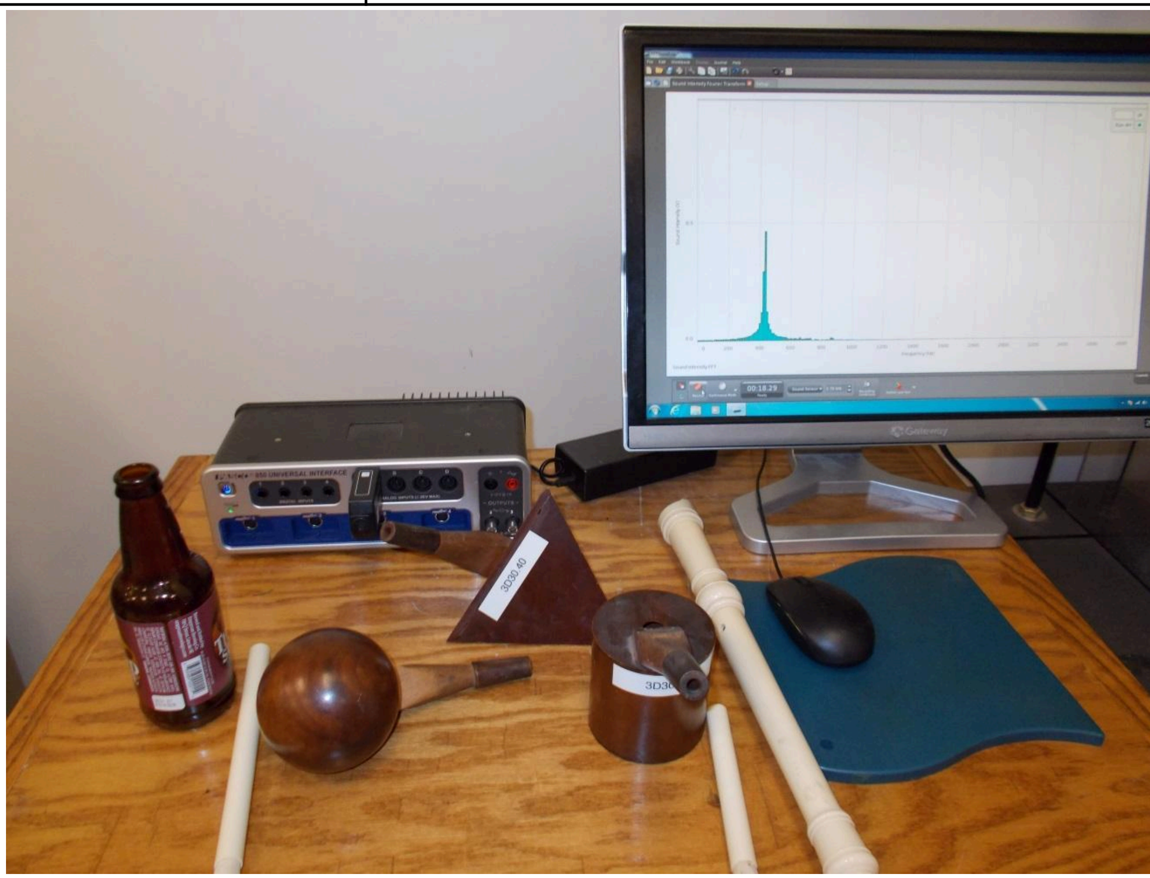
Bloogles/Kroogah Tubes

	See the article in AJP 42(4), 278 for an explanation of singing corrugated pipes.



Location: Fa2

OSCILLATIONS AND WAVES	3D30.40	INSTRUMENTS
Resonance Cavities		
Helmholtz Resonators		
	The resonant frequency depends on the volume not the shape. The volume of the sphere is about 268 cc, The tetrahedron, 259 cc and the cylinder, 368 cc. Use the FFT (capstone file FFTSound.cap) to show the difference between a pipe and a Helmholtz resonator.	

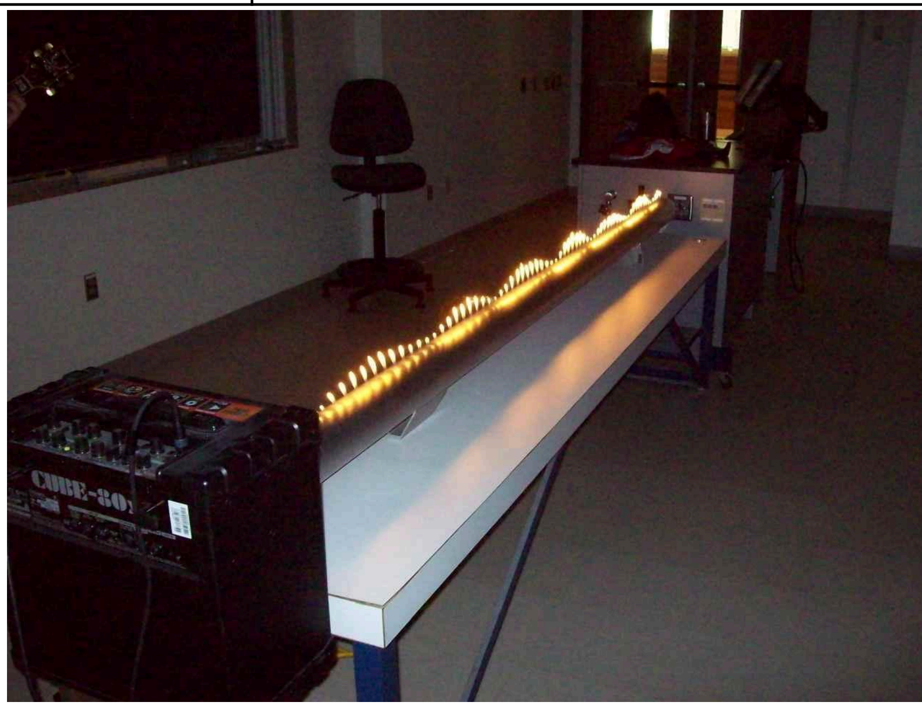


Location: Fa3, Ed6

OSCILLATIONS AND WAVES	3D30.50	INSTRUMENTS
Resonance Cavities		

Ruben's Tube

	Flames dance to the tunes of standing waves. This demonstration is more complicated than it might seem. Seal the open end of the tube with dental dam and scotch tape. Use a Bunsen burner to make it easier to light up the tube.



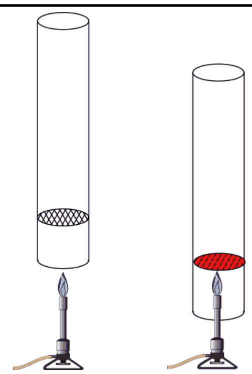
Location: FaT, Fb4, Fb5

OSCILLATIONS AND WAVES	3D30.70	INSTRUMENTS

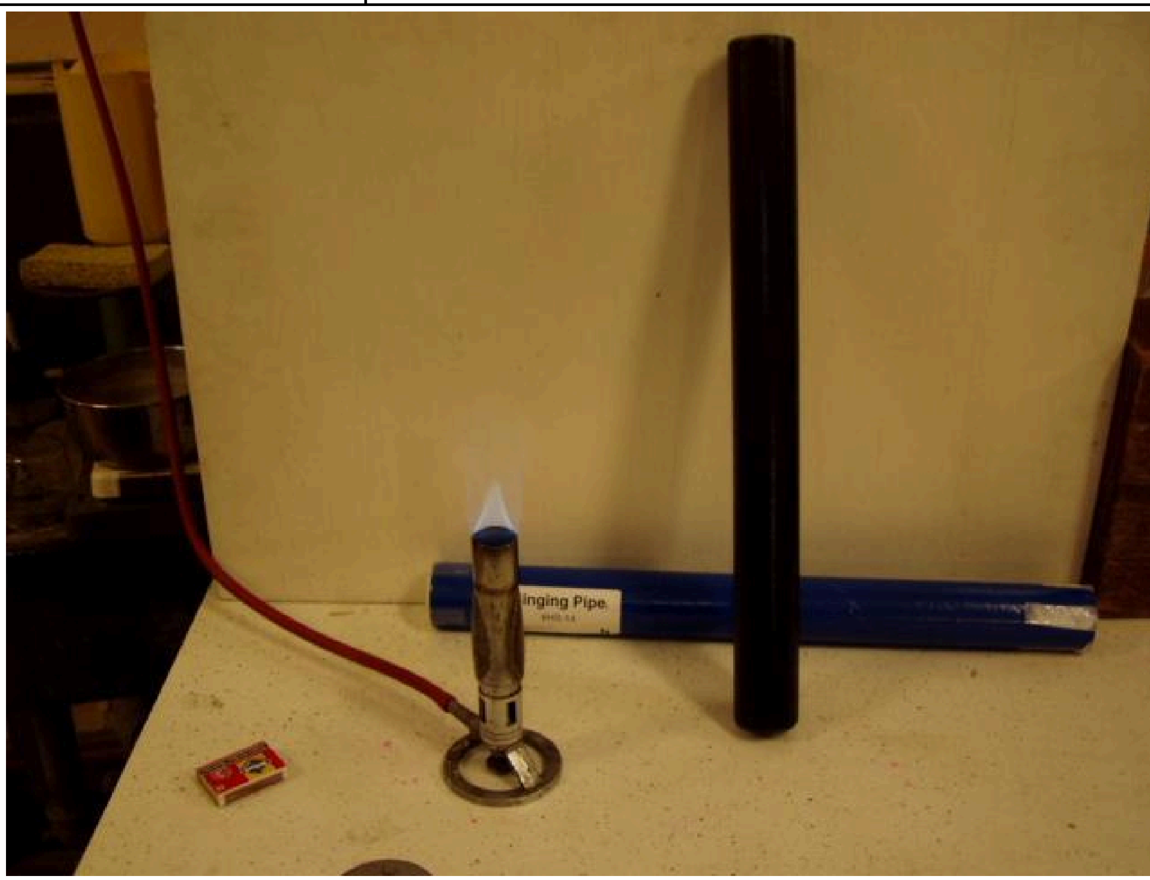
Resonance in Cavities

Hoot Tubes

Disc 11-07



Long tubes that have screen wire near one end are held over a burner. Heat until the screen is hot. The tube sounds when removed from the flame when held vertically, but stops when held horizontally.



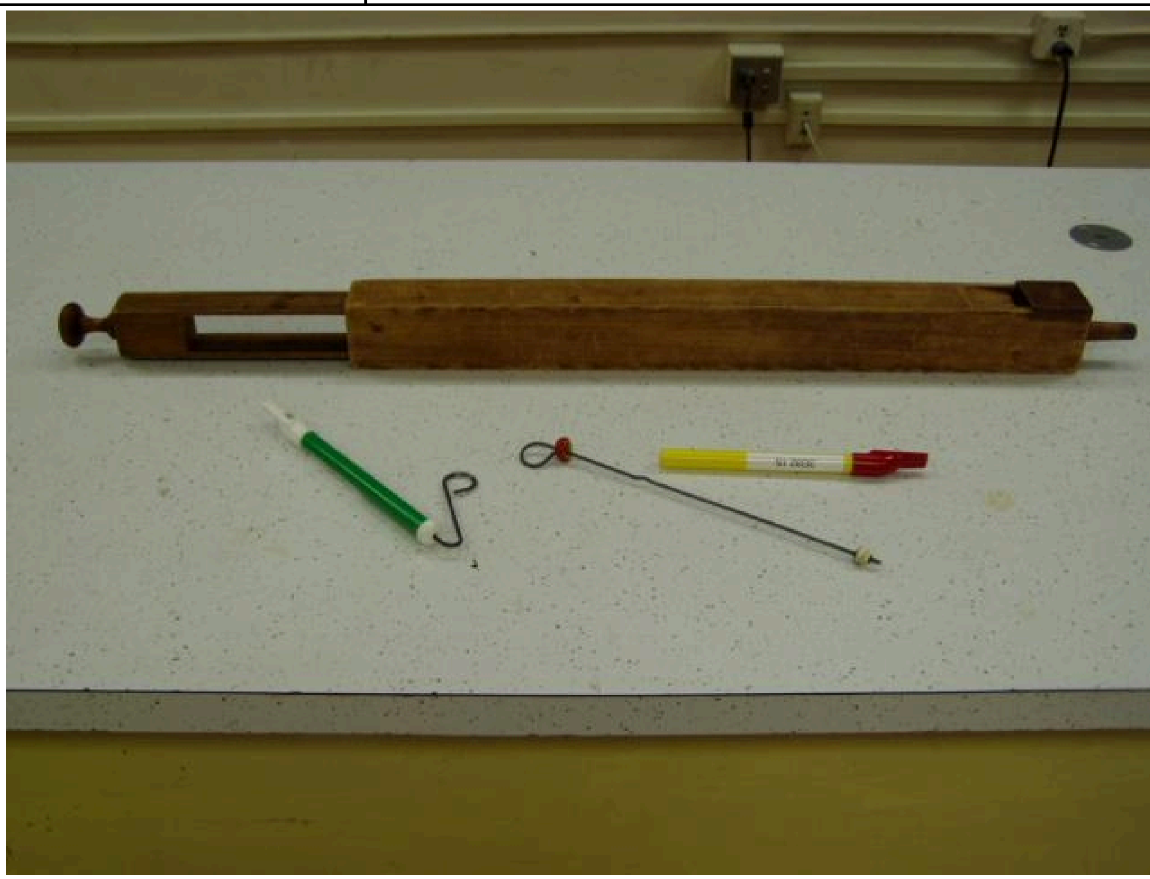
Location: Fa3

OSCILLATIONS AND WAVES	3D32.15	INSTRUMENTS

Air Column Instruments

Slide Whistle

	A whistle with a sliding piston. One of the whistles has been disassembled for inspection. Also shown in the photograph is a variable length organ pipe.

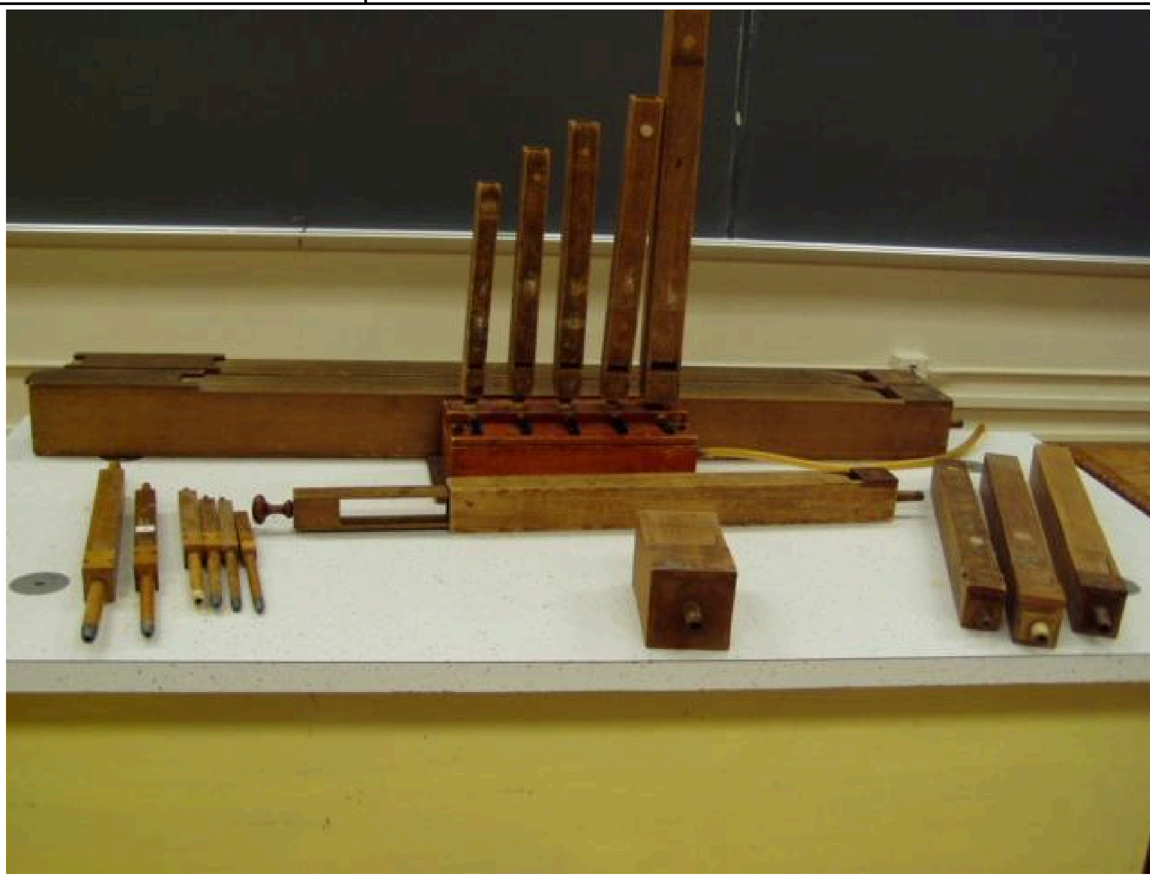


Location: Fa3

OSCILLATIONS AND WAVES	3D32.25	INSTRUMENTS
Air Column Instruments		

Organ Pipes

	Various organ pipes, some open-open and some open-closed. Some can be blown as either. There is also a small organ that can hold several pipes at once.



Location: Fa4

OSCILLATIONS AND WAVES	3D32.40	INSTRUMENTS
Air Column Instruments		
Demonstration Trumpet		
	A mouthpiece is connected to a hose with a funnel for a bell. The various parts can be removed to show their function.	

Location: Fa4

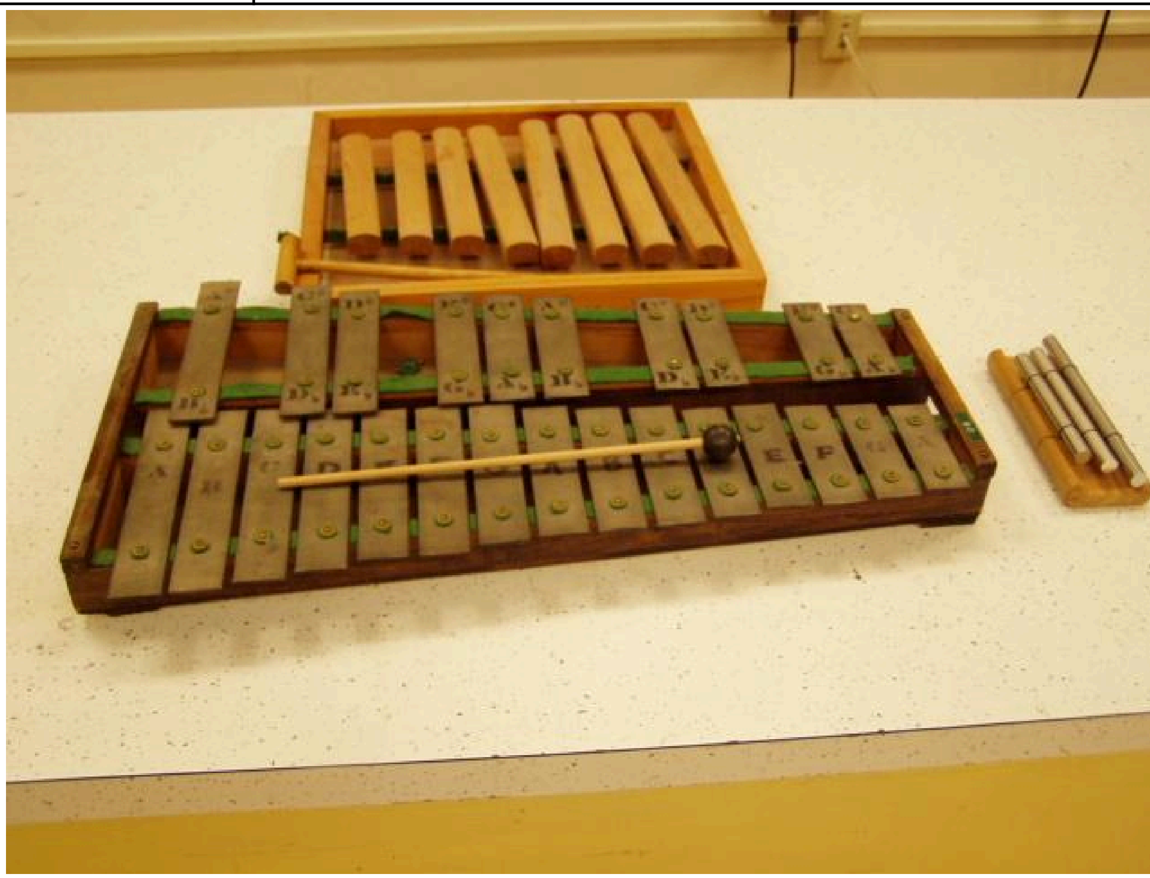
OSCILLATIONS AND WAVES	3D32.45	INSTRUMENTS
Air Column Instruments		

PVC Instruments

	Flutes and pan pipe sets made of plastic pipe. A tygon "clarinet" and a jig to make transverse PVC flutes are shown in the photograph.

Location: Fa5

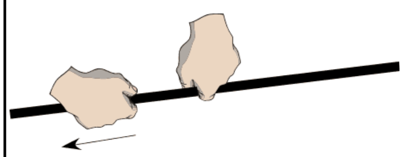
OSCILLATIONS AND WAVES	3D40.10	INSTRUMENTS
Resonance in Plates, Bars, and Solids		
Xylophone		
	A couple of small xylophones as well as a set of mounted steel bars can be used to discuss vibrations of a bar. In particular notice that the octave does not have half the length of the octave below.	



Location: Fa6

OSCILLATIONS AND WAVES	3D40.15	INSTRUMENTS
Resonance in Plates, Bars, and Solids		
Musical Sticks		
	A set of sticks that give you the musical scale when dropped.	

Location: Fa7

OSCILLATIONS AND WAVES	3D40.20	INSTRUMENTS
Resonance in Plates, Bars, and Solids		
Singing Rod		
Disc 10-08		
	A long aluminum rod will sing when it is stroked along its length with rosin and supported at its center. Find the center by balancing the rod on your finger. Rub some rosin on your free hand and vigorously stroke the rod. You will need to squeeze hard. Also try holding the rod at a point 1/3 or 1/4 of its length to excite higher harmonics.	

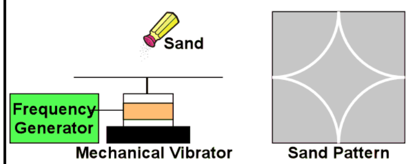
Location: Fa7

OSCILLATIONS AND WAVES	3D40.30	INSTRUMENTS

Resonance in Plates, Bars, and Solids

Chladni Plate

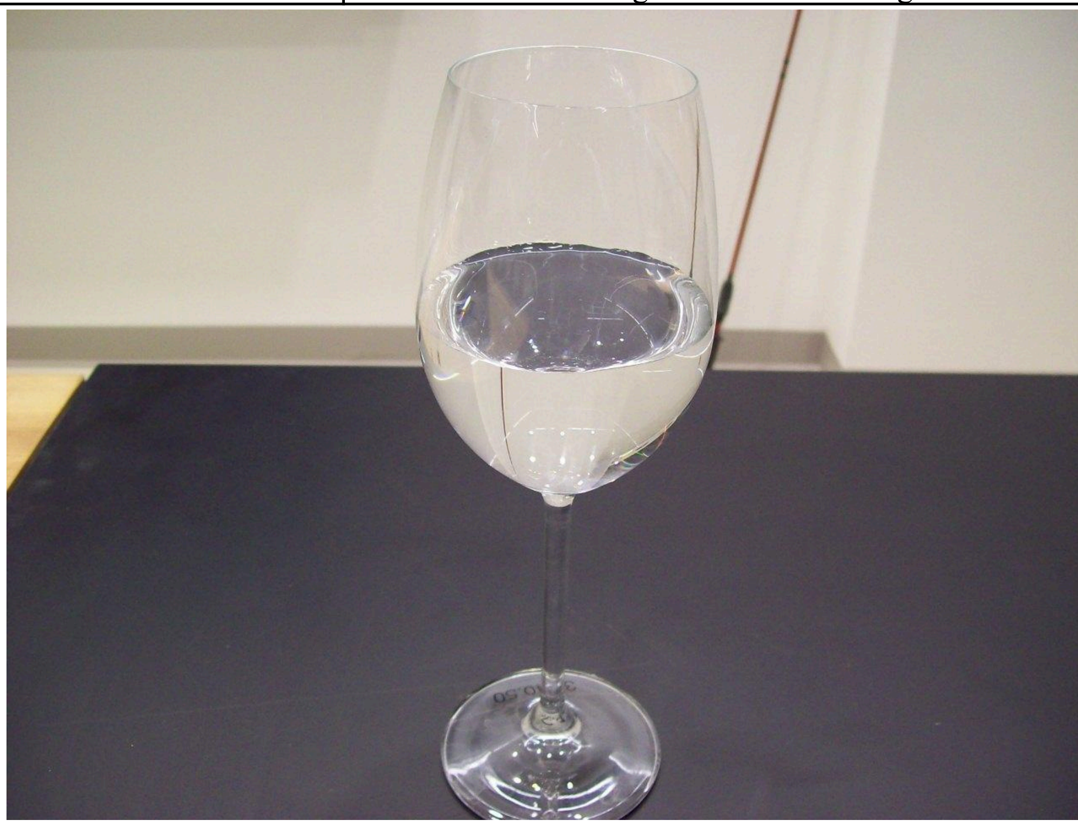
Disc 09-30



A square plate is clamped at its center. Sand is sprinkled on it and the place is excited with a bow. The sand will show the nodal lines of the excited pattern. The pattern will change depending on where you bow on the edge. There are also plates with different shapes that can be used.
Alternatively, the plate can be excited using a mechanical vibrator and a frequency generator as shown.

Location: Fa7, Fb4

<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3D40.50</td><td>INSTRUMENTS</td></tr>
<tr><td colspan="3">Resonance in Plates, Bars, and Solids</td></tr>
<tr><td colspan="3"><h1>Musical Goblet</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Rub the rim of a wine goblet with a wet finger.</td></tr>
</table>



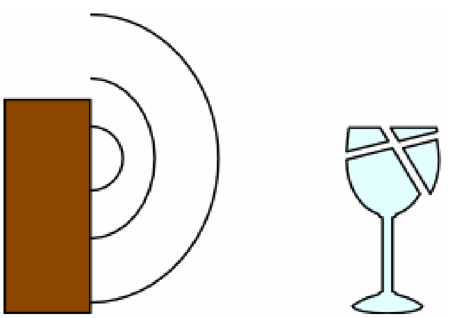
Location: Fa7

Resonance in Plates, Bars, and Solids

Chinese Spouting Bowl

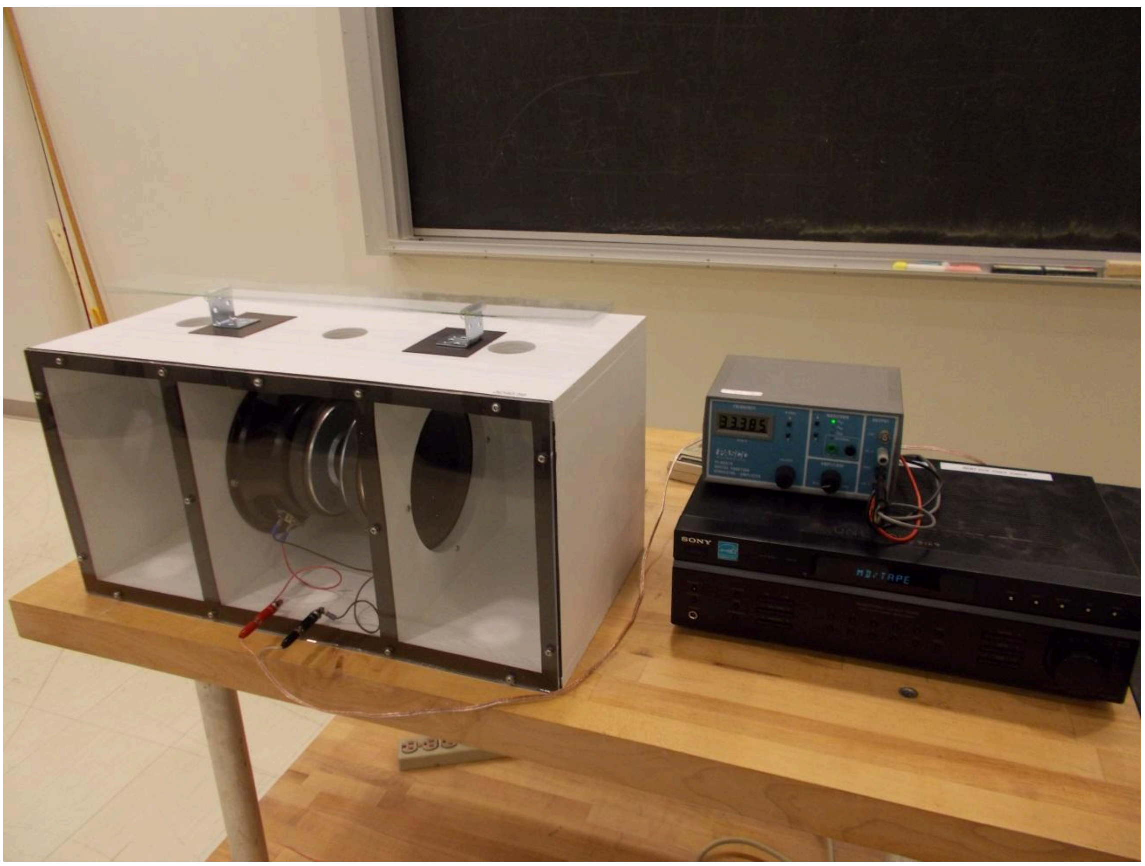
Fill Bowl about half full. Wash hands thoroughly. Moisten your hands. Rub your hands back and forth in opposite directions on the brass handles. As the vibrations build, the water will spout up and out of the bow. Long steady strokes with a fairly light touch works best.

Location: Fb1

<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3D40.55</td><td>INSTRUMENTS</td></tr>
<tr><td colspan="3">Resonance in Plates, Bars, and Solids</td></tr>
<tr><td colspan="3"><h1>Shattering Goblet</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Large amplitude sound at the resonant frequency is directed at a wine glass, goblet, or beaker. We use 400 ml beakers whose resonant frequency is about 1280 Hz. Mount the beaker with the spout <u>pointed horizontally</u>. Find the resonant frequency before the demonstration using the strobe (input 1/2 V, level 60). The strobe will help you find the exact frequency at high amplitude which is usually a little lower than the low amplitude frequency. Use ear protection.</td></tr>
</table>

Location: Fb1, Fb4

<table>
<tr><td>OSCILLATIONS AND WAVES</td><td>3D40.56</td><td>INSTRUMENTS</td></tr>
<tr><td colspan="3">Resonance in Plates, Bars, and Solids</td></tr>
<tr><td colspan="3"><h1>Glass Breaker</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">A glass strip (3” x 24” and 3/32” thick is placed on a box in which there are two speakers. The supports should be placed 0.227 times the length of the glass from the ends (for small amplitudes, it’s .25 L). As the speakers are driven by an oscillator at resonance (about 33.4 Hz), the glass oscillates. If the amplitude is high enough, the glass will break.</td></tr>
</table>



Location: Fb3, Fb4, Fb5

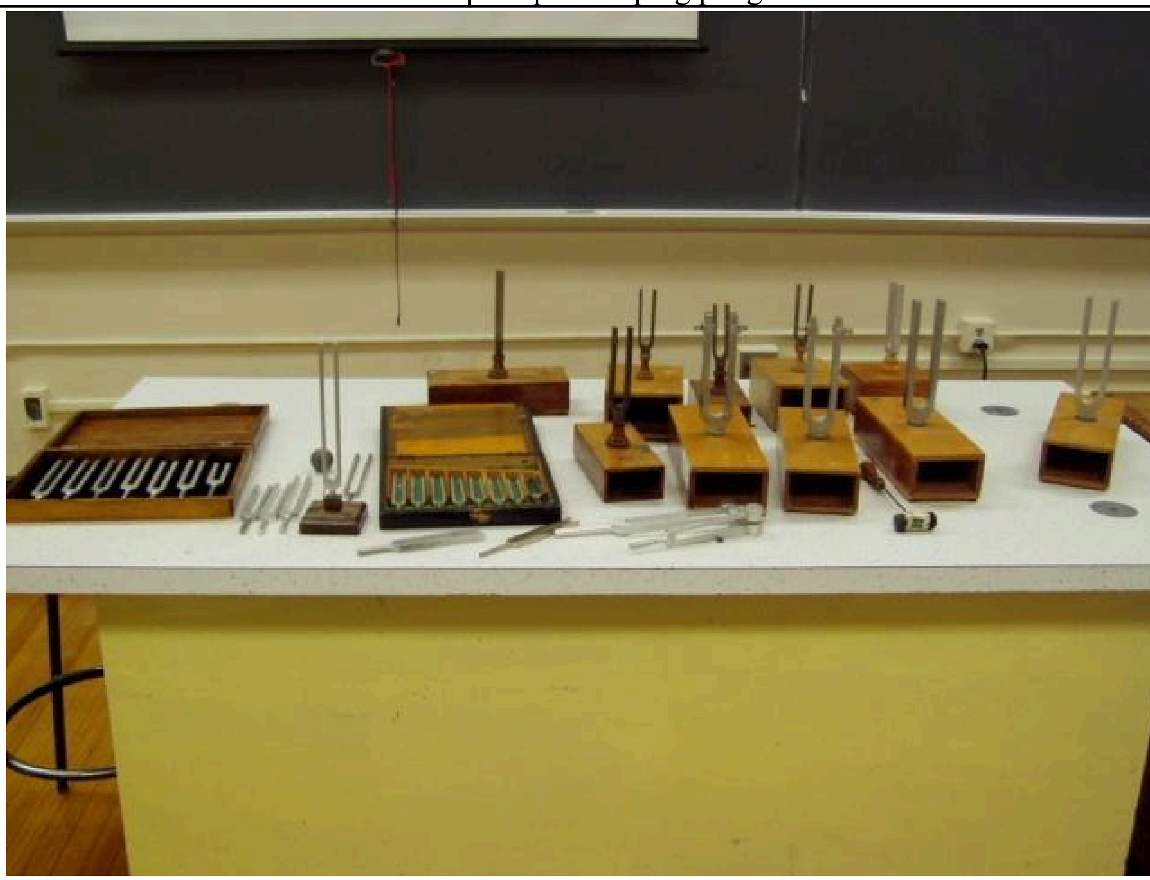
OSCILLATIONS AND WAVES	3D40.65	
Resonance in Plates, Bars, and Solids		
Bull Roarer		
	The Australian "Bull Roarer" produces a load noise due to eddy currents in the air. Insert your finger inside the loop of string and swing the bull roarer about in a vertical circle; it is important for the bull roarer to be spinning about its longitudinal axis as well as in the vertical circle, so the string must alternately twist up and then untwist and twist the other way.	

Location: Fa7

Tuning Forks

Tuning Fork Set

Mounted and unmounted tuning forks of various frequencies. The forks with the large aluminum weights on the tines are to demonstrate the motion of the fork. Use an oscilloscope to display the output of a selection of mounted forks. Show an unmounted fork is inaudible when excited unless its base is held against a resonator. The inaudible excited forks motion can be shown with a suspended ping pong ball.

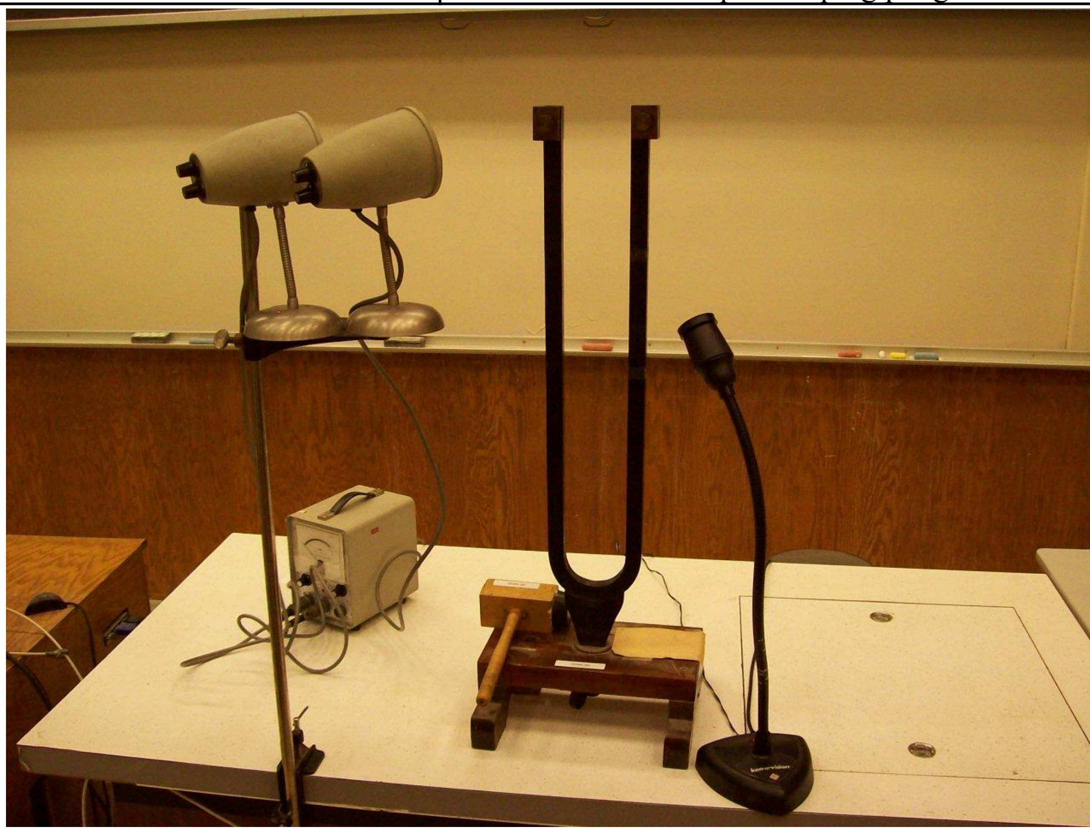


Location: Fb2

OSCILLATIONS AND WAVES	3D46.30	INSTRUMENTS
Tuning Forks		

Low Frequency Tuning Fork

	Tuning fork vibrations may be studied with a strobe and a long fork. The inaudible excited fork motion can be also shown with a suspended ping pong ball.



Location: Fd1

OSCILLATIONS AND WAVES	3E10.10	SOUND REPRODUCTION
Audio Systems		
Audio Cart		
	Complete audio system on a cart.	

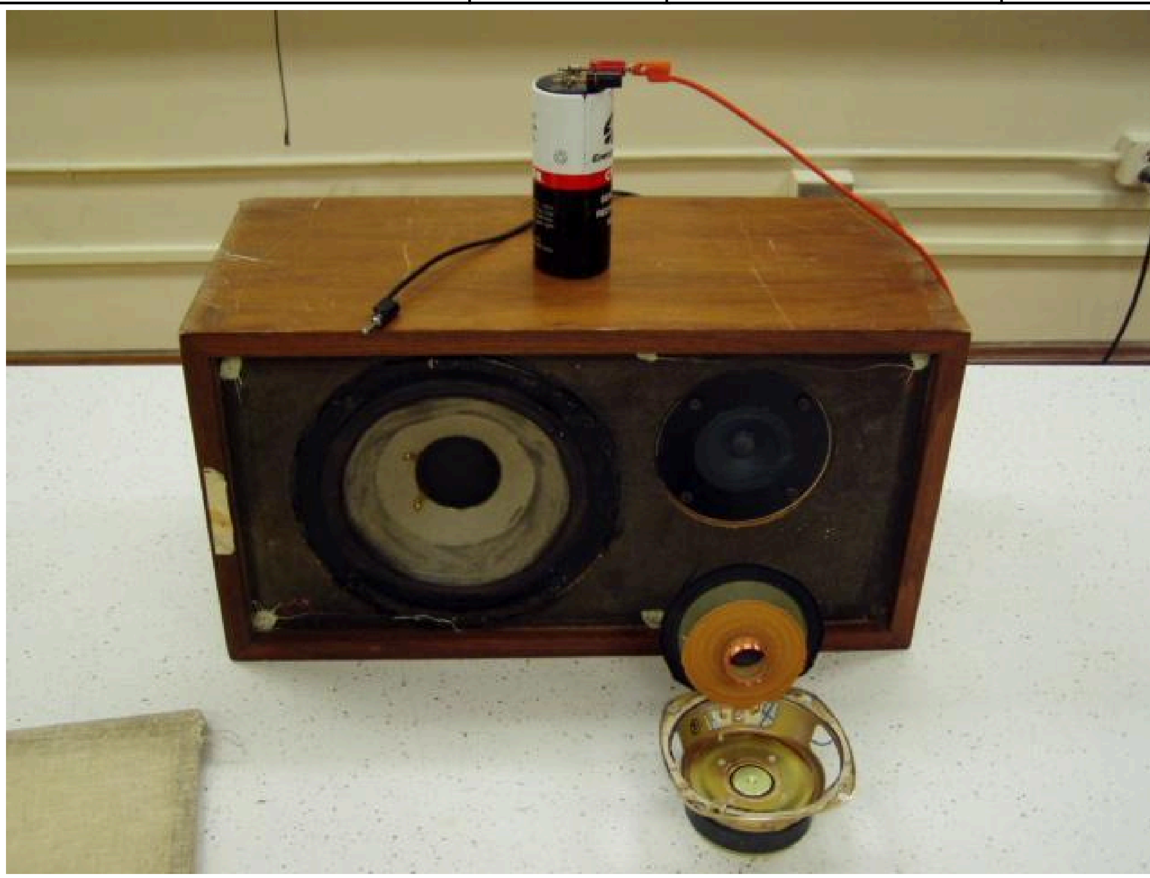
Location: Ed3, Fb5

OSCILLATIONS AND WAVES	3E20.10	INSTRUMENTS

Loudspeakers

Dissected Loudspeaker

A loudspeaker is taken apart to show the coil, magnet and speaker cone. Use a 2 volt battery to show the motion of the speaker cone of the intact speaker.



Location: Fb3