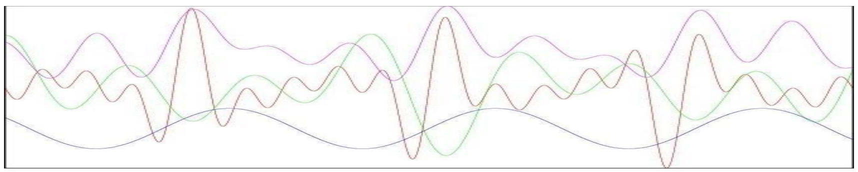
Music, Math, and Motion

with Dr. E.J. Zita & Dr. Arun Chandra
The Evergreen St. College



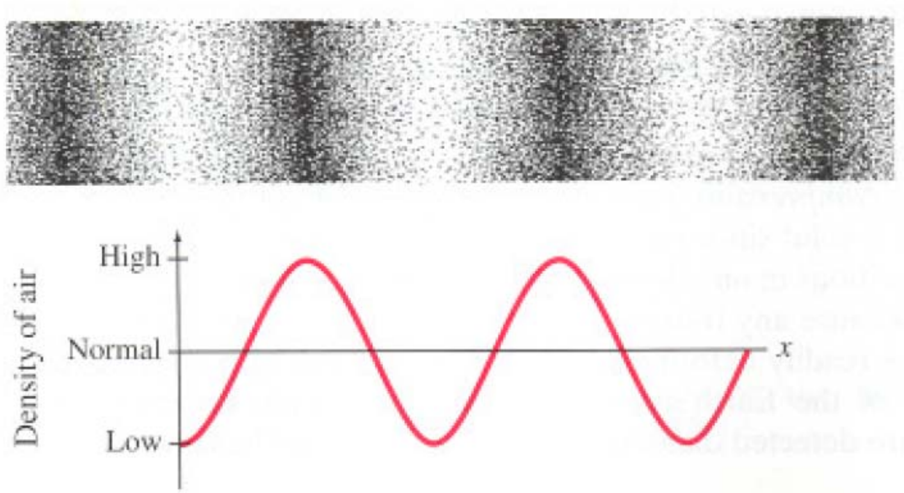
Winter week 2

Tuesday 13 Jan.2009

Physics of Sound Overview

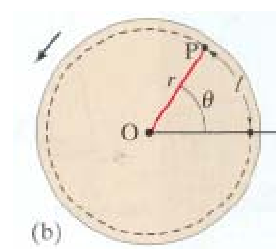
- What is sound?
- Waves: simple harmonic motion
- Representing sound waves mathematically
- Sources of sound
- Wavelength and frequency
- Speeds of sounds and sources
- Perception of sound
- Resonance
- Applications
- Sound waves in nature

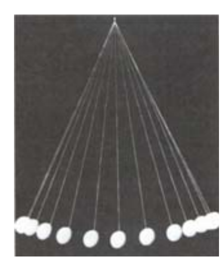
What is sound?

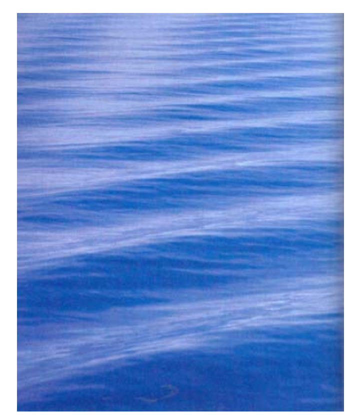


Sound waves: Compressions and expansions of a medium such as air

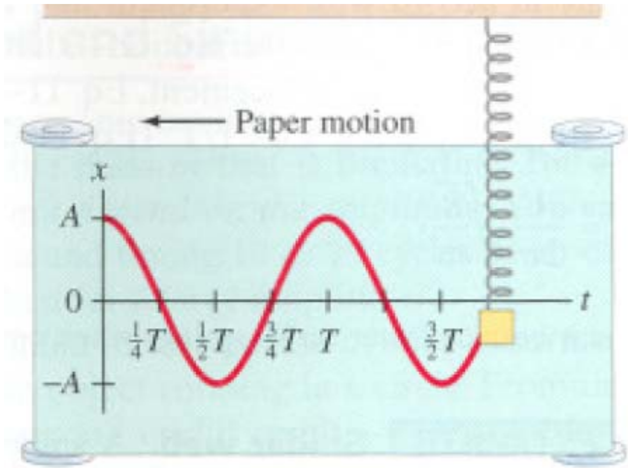
Waves & simple harmonic motion







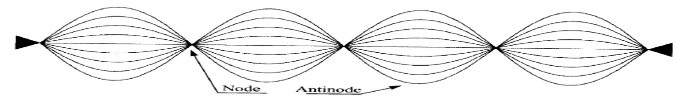
Representing sound mathematically



$$x(t) = A\cos(\omega t) = A\cos(2\pi f\, t)$$

Sources of Sound

Strings



Open pipes

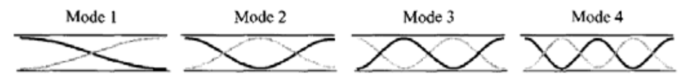


Figure 8.16
Displacement modes of open-ended pipe.

Closed pipes

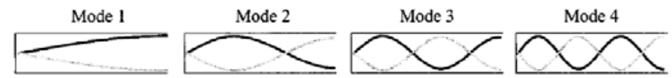
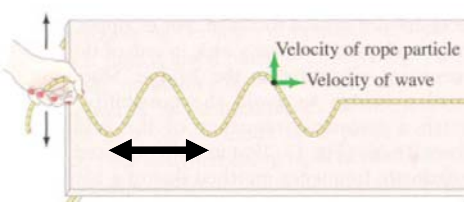


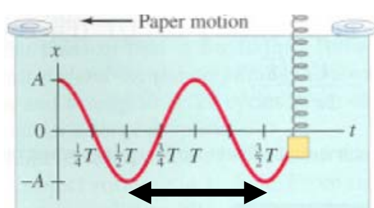
Figure 8.17
Displacement modes of closed-ended pipe.

Wavelength and frequency



Wavelength λ

space



Period T

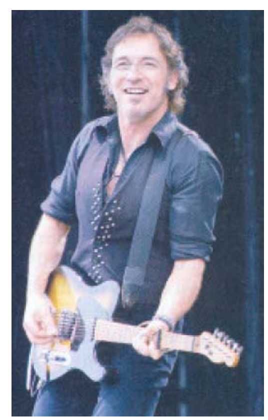
time

$$f = \frac{1}{T}$$

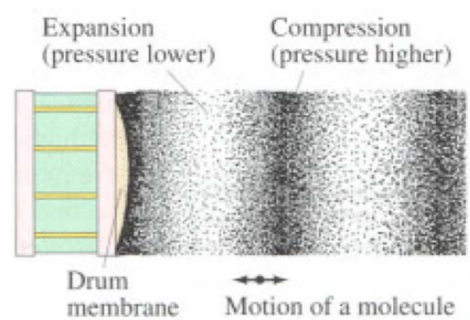
$$\textit{time}(\text{seconds}), \textit{Period} = T(s)$$

$$\textit{frequency} = f\left(\frac{1}{s}\right) = (\textit{Hertz}) = (\textit{Hz}),$$

Speeds of sounds and sources

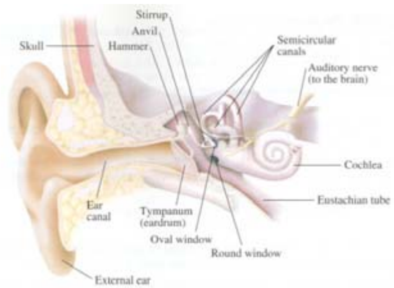


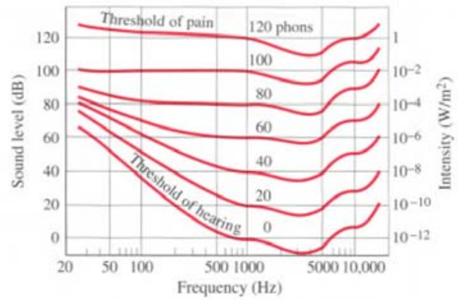
$$speed_{\substack{\text{of transverse}\\ \text{waves on string}}} = \sqrt{\frac{Tension}{mass/length}}$$

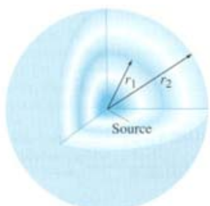


$$speed_{\substack{\text{of longitudinal}\\ \text{waves in air}}} = \sqrt{\frac{Elastic\ restoring\ force}{Inertia}} = \sqrt{\frac{Air\ pressure}{air\ density}} = \sqrt{\frac{P}{n}}$$

Perception of sound







Intensity = Power / Area

FIGURE 12–6
Sensitivity of the human ear as a function of frequency (see text). Note that the frequency scale is "logarithmic" in order to cover a wide range of frequencies.

Resonance: an object oscillates at the same frequency as the driving source

http://www.labinalorry.co.uk

http://www.youtube.com/watch?v=j-zczJXSxnw

Harmonics

Females typically beat wings 400 times per second

Males typically beat wings 600 times per second

What harmonic of both frequencies matches?

1200 Hz = **3***400 = **2***600

Mosquitoes Match Wing Beats Before Mating

Mosquitoes match wing beats before mating; Scientists hope discovery can limit reproduction

By RANDOLPH E. SCHMID AP Science Writer The Associated Press
WASHINGTON January 8, 2009 (AP)

This undated handout file photo provided by the Agriculture Department shows an aedes aegypti... (AP)

Researchers at Cornell University have discovered that Aedes aegypti mosquitoes — the ones that spread diseases like yellow and dengue fever — alter their wing vibrations in a mating signal.

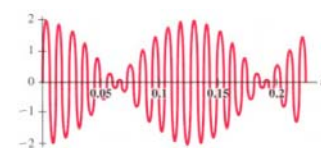
The good news is that the finding could lead to better ways to control mosquitoes, according to Ronald R. Hoy, an author of the report published Thursday in the online edition of the journal Science.

http://abcnews.go.com/Technology/wireStory?id=6604532

http://academic.evergreen.edu/curricular/mmm/documents/SoundScience/MosquitoesMatcWingbeats.pdf

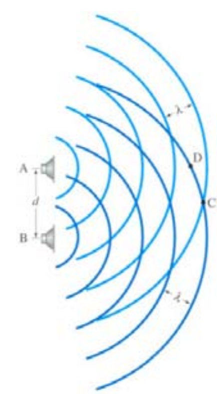
Applications

- Doppler effect



- Beats

- Sonic boom

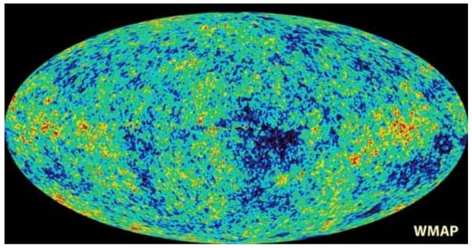


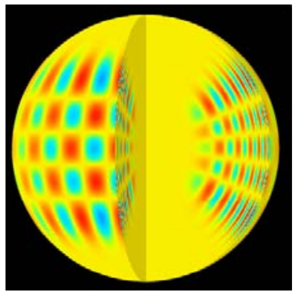
- Ultrasound

- Interference

Sound waves in nature

- Big Bang
- Pulsating stars
- Planets' atmospheres
- Insects & Trees
- Whales drink sounds
- Sand dunes
- Chimps
- … more …





Whales drink sounds

By Rachel Ehrenberg
February 9th, 2008; Vol.173 #6 (p. 84)

Whales may receive sounds through the throat in addition to taking them in through the jaw, a new study finds. Understanding where sound enters the head of the Cuvier's beaked whale could point to the original acoustic pathway for all whales and provide insight into how sonar affects the animals.

The Cuvier's beaked whale is one of roughly 80 species of toothed whales, along with pilot whales, dolphins, orcas, sperm whales and others. Toothed whales are deep divers that hunt for food using echolocation—they emit sounds that bounce off objects and return to the whale, giving a "picture" of the prey's shape, size, and whereabouts.

. . . Cranford modeled the exact geometry of the whale's head and all of its physical properties, such as bone and tissue density. The researchers then fed mathematical "sounds" into the model and watched how the sounds traveled.

To Cranford's surprise, sounds coming from directly in front of the whale seemed to travel under its jaw, not through the acoustic window. The sound waves then went through the throat, and passed through a hole in the back of the jaw to the fat by the ear.

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

http://academic.evergreen.edu/curricular/mmm/documents/SoundScience/WhalesDrinkSounds.pdf

Ultrasound from pine bark beetles & dying trees

The ultrasonic din of dying trees inspires a new kind of research to save forests from beetle attacks — and battle climate change

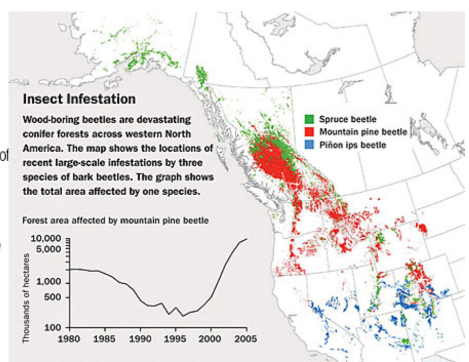
August 30th, 2008; Vol.174 #5

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC
http://www.sciencenews.org/view/feature/id/35257

Home › August 30th, 2008; Vol.174 #5 › Feature

POP CHIRP BITE CRUNCH CHEW

ENLARGE | Composer David Dunn listens in on the sounds of piñon pine trees and the bark beetles that infest them. The bugs have felled thousands of trees across New Mexico.



The spruce bark beetle has already taken a Connecticut-sized bite out of Alaskan pine forest. And bark beetle outbreaks have desolated thousands of square kilometers of western North American forests, incidentally releasing thousands of tons of carbon into the atmosphere. The additional carbon is a concern because of its link to climate change.

They want to play deceptive ultrasound to confuse the tree-devouring bugs, luring them away from vulnerable forests and keeping the insects from spreading to new territories.

Goals and activities

Welcome to the Winter Physics of Sound page for Music, Math, and Motion

MMM Physics of Sound will meet Fridays from 1:00 - 5:00 in the CAL (Lab II first floor)

Homework help sessions will be held Thursdays from 3:00 - 5:00 in the CAL. (If nobody shows up before 4:00, the help session will end early.) This can also be a time for us to do advanced (calculus-based) work, if there is interest.

Support in basic math skills is also available at the QUASR, the peer-learning math center in the library.

In fall quarter we learned the basics of waves and the physics of sound, with a focus on hands-on workshop with a little math.

Now in winter quarter we will dig deeper into the same material, with goals of:

- *deeper understanding of the waves and physics of sound, qualitatively (via discussion more than math)*
- *strengthening and developing quantitative skills by using more math and solving problems from our textbook*
- *integrating deeper qualitative understanding with stronger quantitative skills for a good thorough grasp of key issues in physics of music.*

To this end, we will work methodically through the two key chapters of Giancoli's physics that we read last quarter, Ch.11 (Vibrations and Waves) and Ch.12 (Sounds), using

- lecture and discussion
- seminar and jigsaw learning
- working math-based problems together
- hands-on workshops

Students will also be invited to bring relevant articles or issues to class for discussion.

Physics of Sound syllabus

WEEK	Giancoli reading
wk.1: Tues.6.Jan.	Introduction and logistics
wk.2: 15-16 Jan.	Ch.11: 1, 2, 3, 5 (Simple Harmonic Motion)
wk.3: 22-23 Jan.	Ch.11: 6, 7, 8, 9 (Resonance, Waves, Energy)
wk.4: 29-30 Jan.	Ch.11: 9, 10, 12, 13 (Intensity, Superposition, Standing waves)
wk 5: 5-6 Feb.	(no physics classes) Midquarter Conferences, possible Midterm
wk.6: 9-13 Feb.	Ch.12: 1, 2, 3 (sound, decibels, loudness)
wk.7: 19-20 Feb.	Ch.12: 4, 5, 6 (Sources of sound - strings and air, Superposition Beats)
wk.8: 26-27 Feb.	Ch.12: 7, 8, 9 (Doppler effect, shock waves, sonic boom, applications)
wk.9: 5-6 Mar.	Summary
wk.10: 9-13 Mar.	presentations, performances, possible final
wk.11: 17-20 Mar.	evaluation conferences

Thursday 3:00-5:00: Physics **Help Session** in CAL

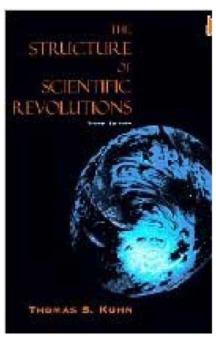
Friday 1:00-5:00: Physics of Sound in CAL (Lab II)

Week 2 overview

Week 2	Tues.13 Jan.	1:00 Overview of Physics of Sound Presentation regarding 1st performance project (due week 3) COM 110
		3:00 Seminar (read these in advance and come prepared with 3 Key Points and 3 Significant Questions on each) * Thomas Kuhn: *Structure of Scientific Revolutions* - **Preface through VII (p.76)** and * Marianne Brun: *Paradigms: the Inertia of Language* (article)
	Wed.14 Jan	Finish reading Kuhn (**through through XII and *Postscript***)
	Thursday 15 Jan.	1:00 Computer Music workshop in ACC for Group C 3:00-5:00 **Moodle workshop** in CAL **required for new students**, recommended for continuing students
	Friday 16 Jan.	1:00-3:00 Physics of Sound in CAL (Ch.11a: 1, 2, 3, 5) for Group P, OR Computer music workshop in ACC for Group C
		3:00-5:00 Seminar: finish discussing Kuhn

http://academic.evergreen.edu/curricular/mmm/#syl

Coming up next: Seminar on Kuhn (first half) and Brün (paradigms)



Do you have questions of FACT about scientific examples in Kuhn?

If so, let's spend a short time answering them before seminar.

Seminar groups