Musical Acoustics

Lecture 5

Simple vibrating systems II

The Pendulum

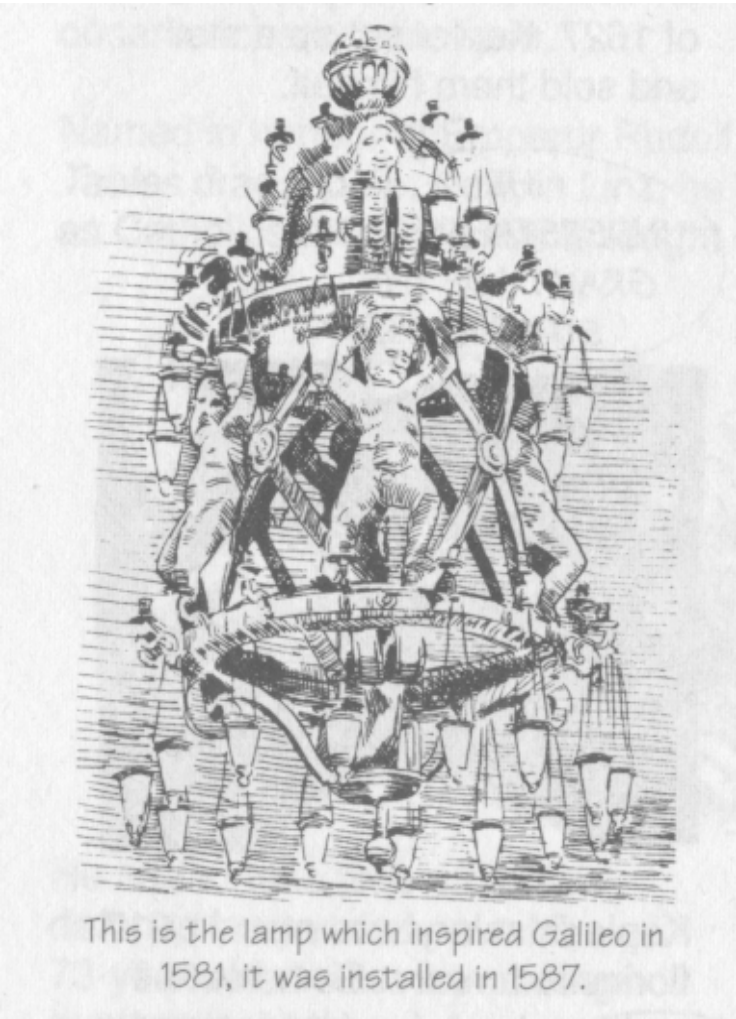
The oscillations of a pendulum (assuming small angle oscillations) is also simple harmonic motion.

The period of a pendulum is

$$T = 2\pi\sqrt{\frac{L}{g}}$$

T is independent of mass.

The Pendulum



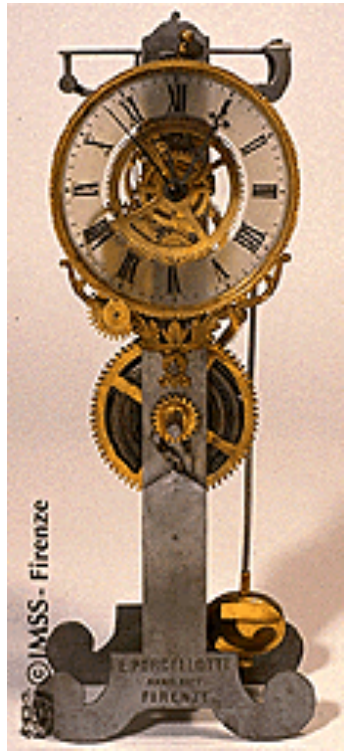
This is the lamp which inspired Galileo in 1581, it was installed in 1587.

Galileo got this idea by watching a chandelier swinging during a church service.

Galileo made the discovery that the period of swing of a pendulum is independent of its amplitude.

Now this discovery had important implications for the **measurement of time intervals**. In 1602 he explained the isochronism of long pendulums in a letter to a friend, and a year later another friend, Santorio Santorio, a physician in Venice, began using a short pendulum, which he called "pulsilogium," to **measure the pulse of his patients**. The study of the pendulum, **the first harmonic oscillator**, date from this period.

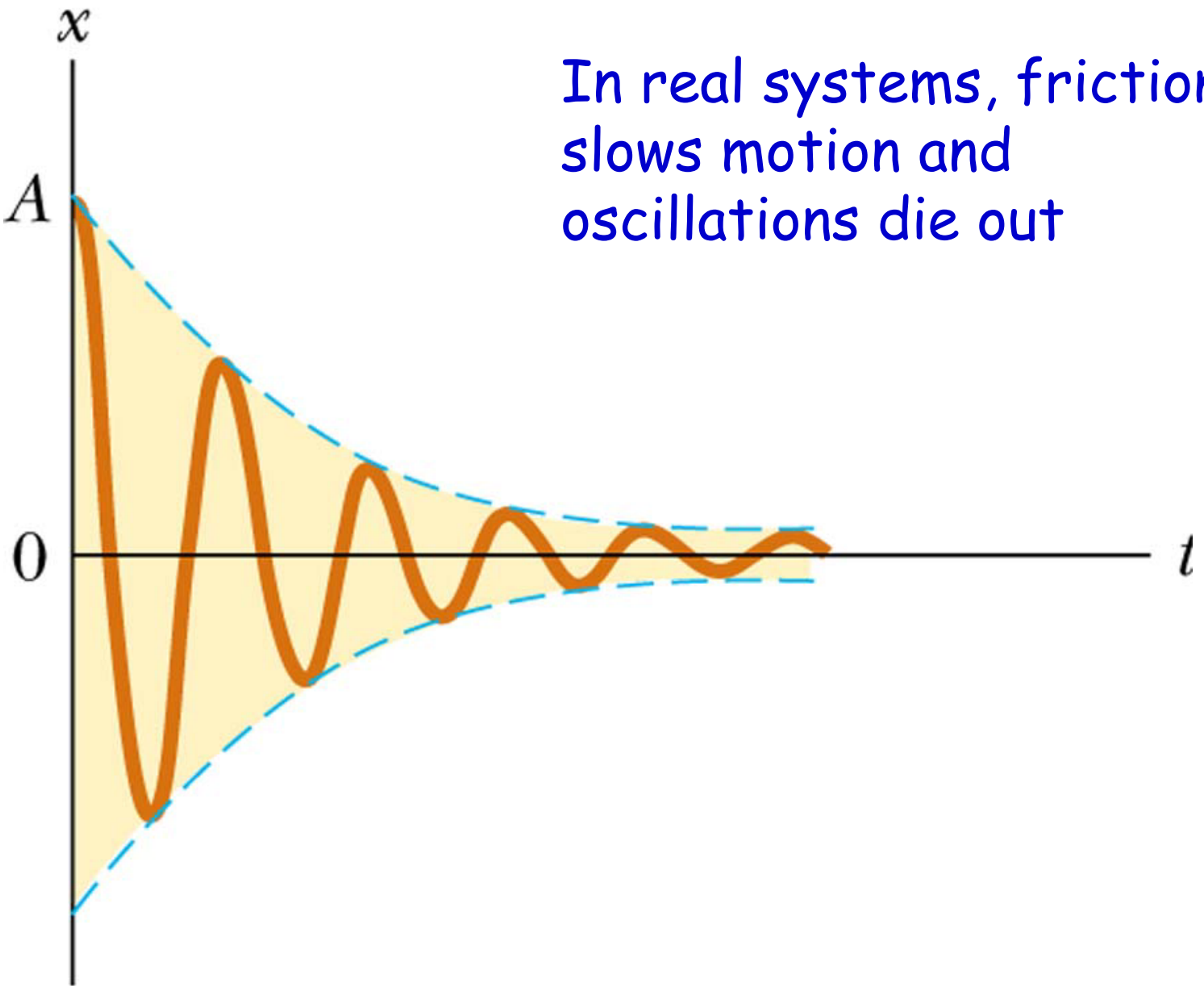
Clocks



1877 Eustachio Porcellotti, Florence
Pendulum Clock

Measuring time accurately was very important for progress in physics! Many of Galileo's experiments depended on knowing the time elapsed.

Damped Oscillations



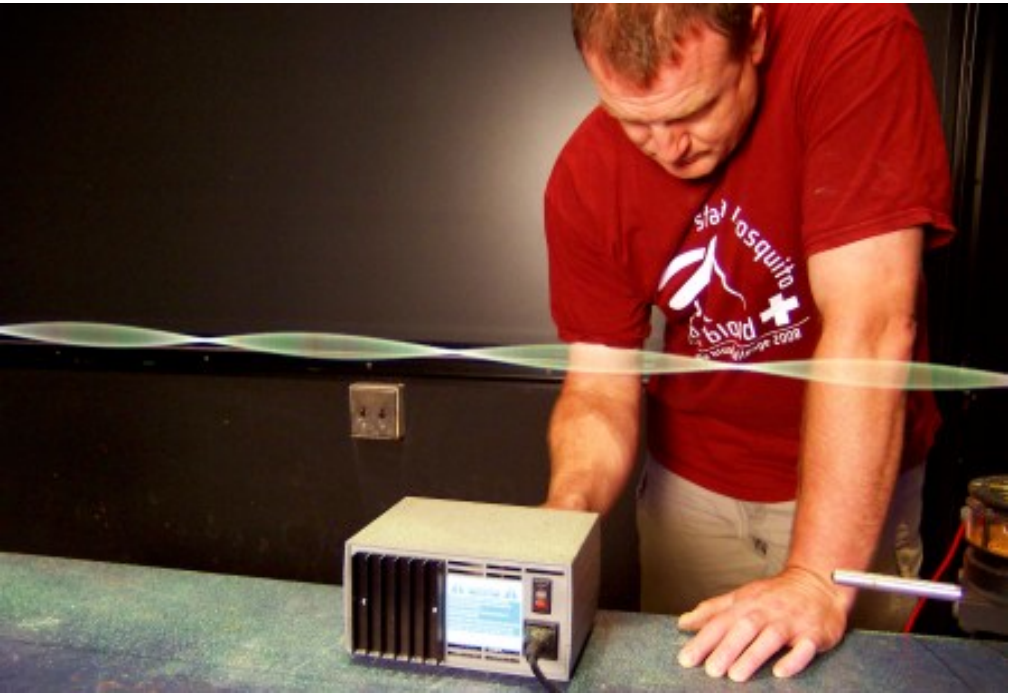
In real systems, friction slows motion and oscillations die out

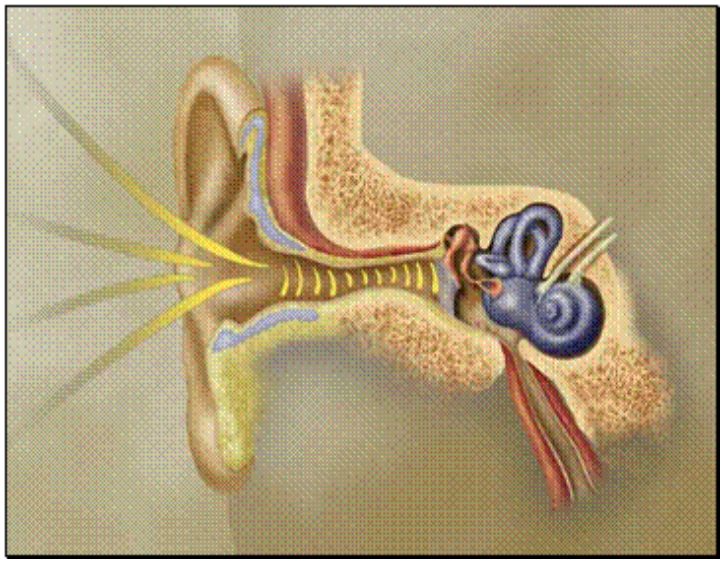
Forced Oscillations

Forced oscillations lead to harmonic motion

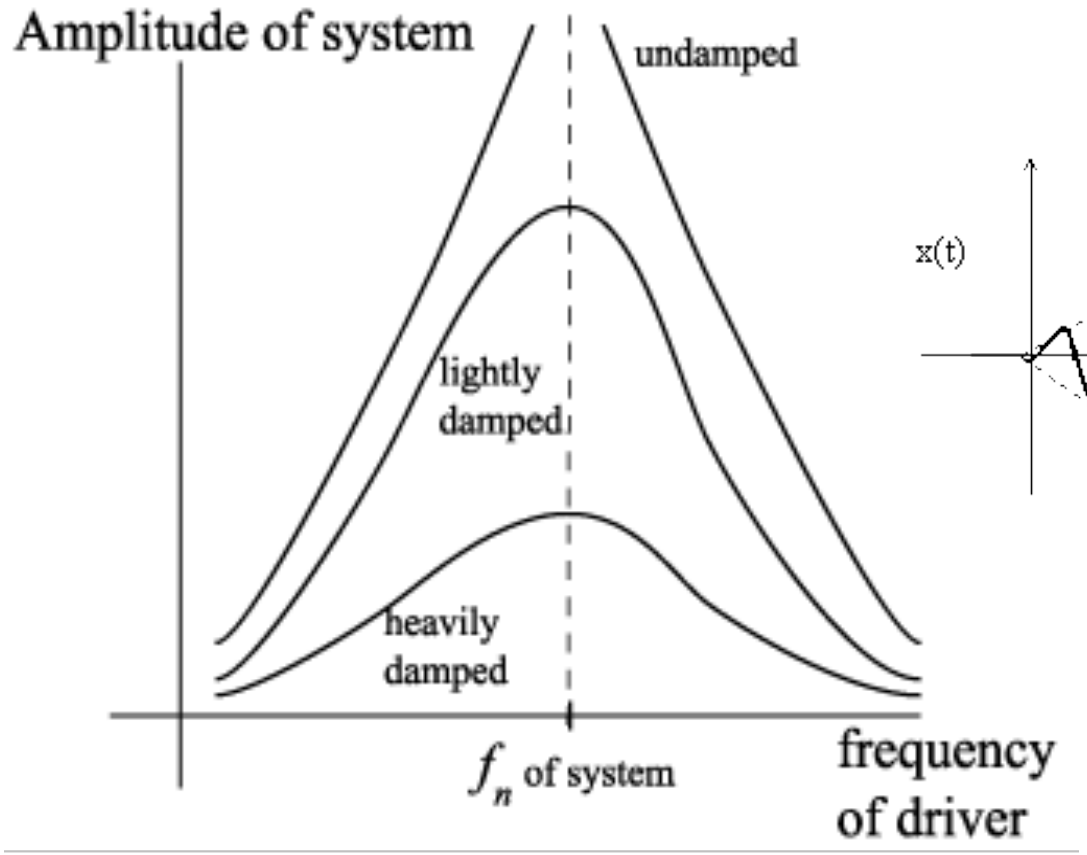
As friction always exists, slow down due to friction must be compensated by forced oscillations to keep amplitude constant.

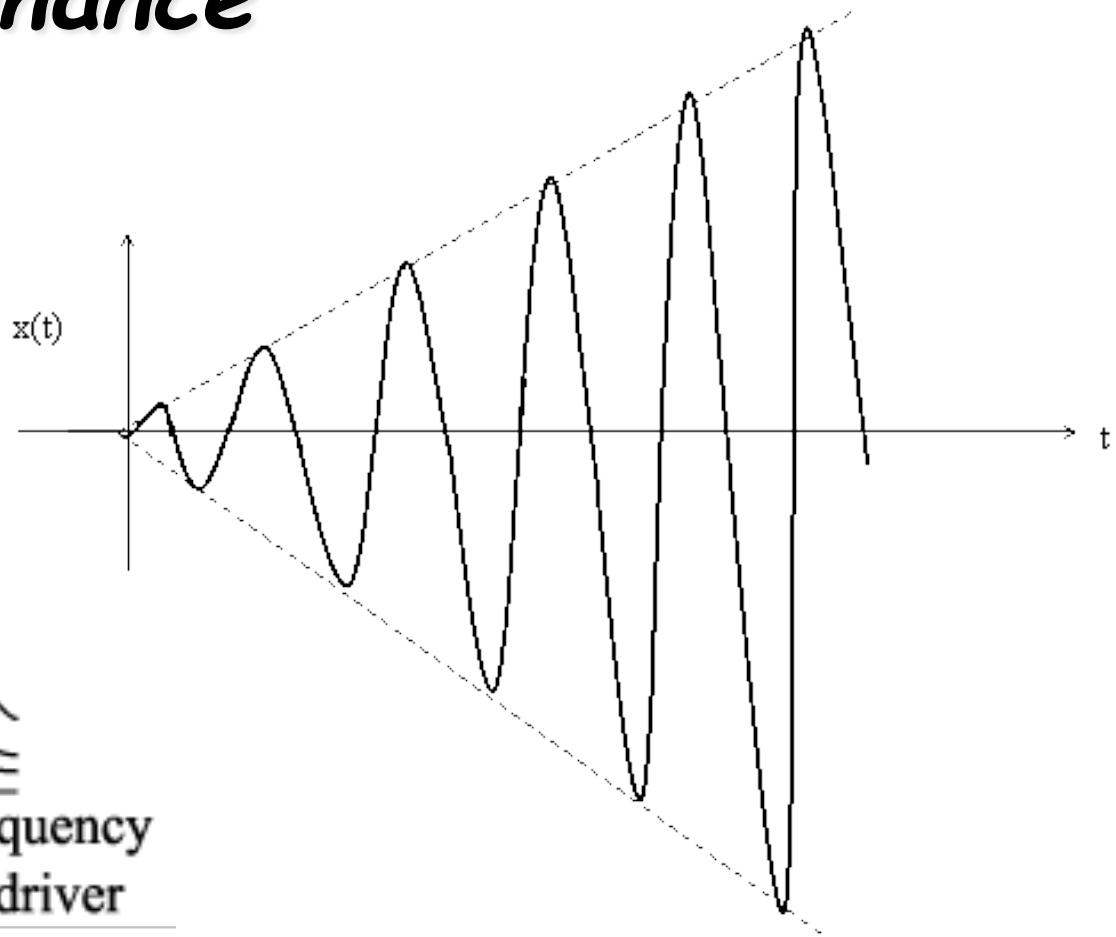
Examples





Resonance

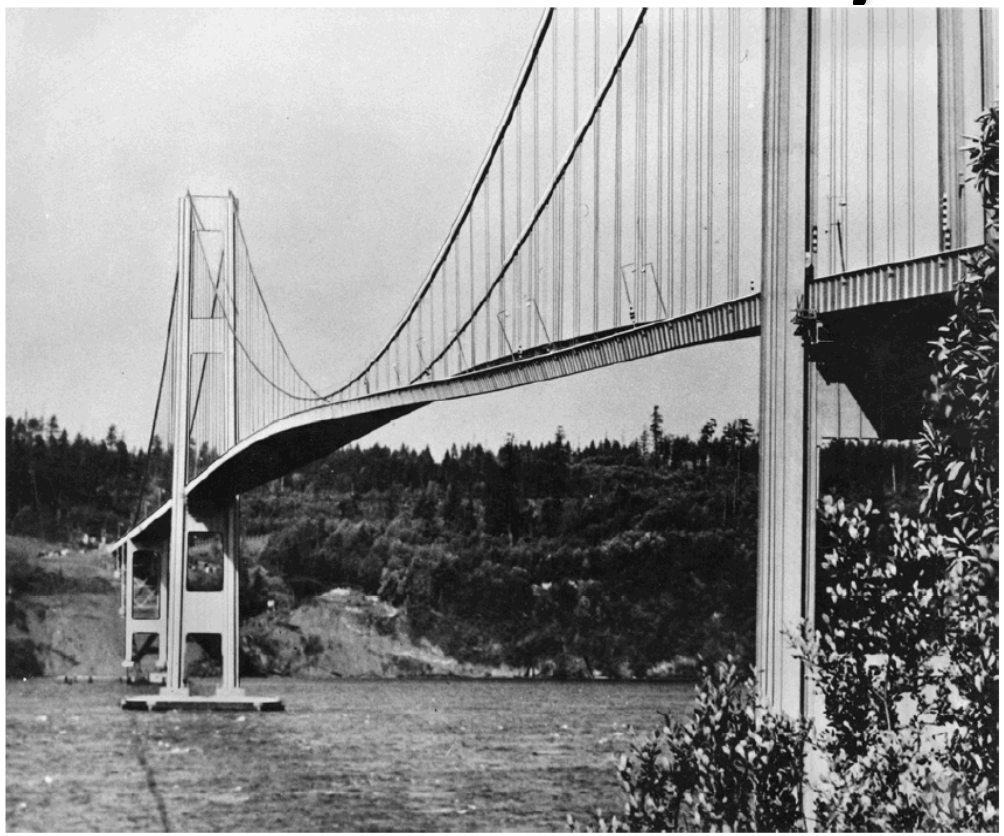




If frequency of forced oscillations are approximately equal to natural frequency f of oscillator, resonance occurs.

→ amplitude of motion becomes large.

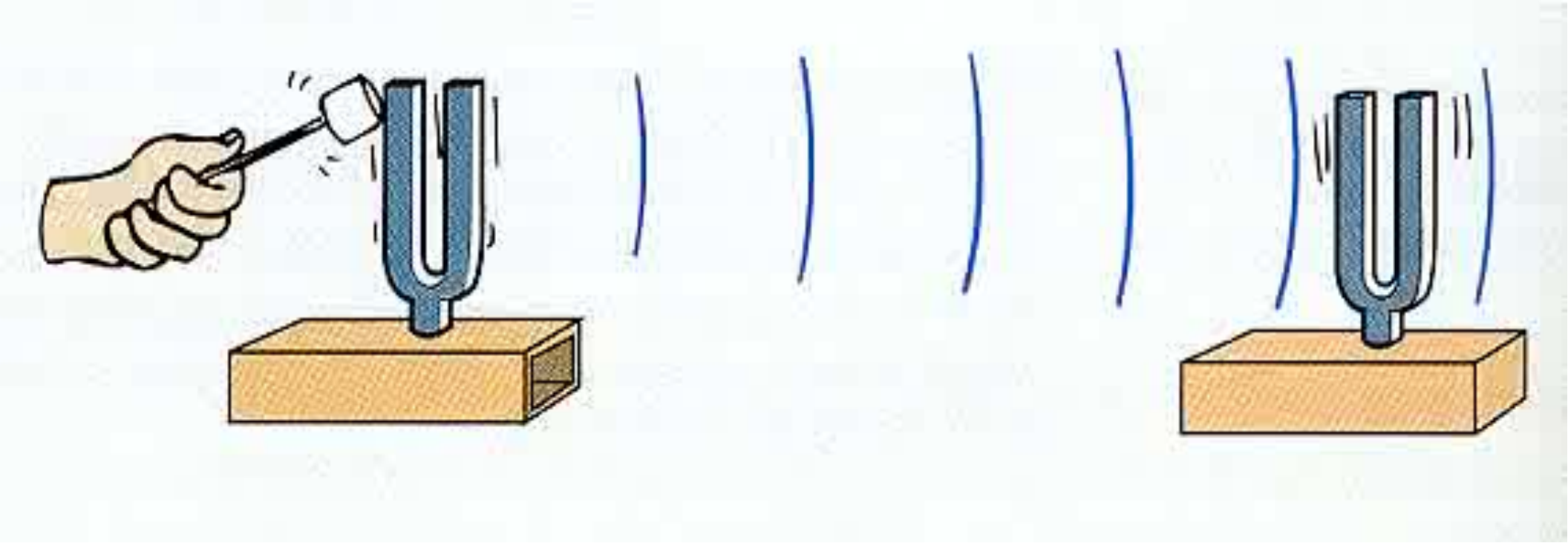
Catastrophic Example



1940: The newly completed Tacoma Narrows Bridge collapses during a windstorm.

Reason: frequency of wind bursts matched natural oscillation frequency of bridge → large amplitude oscillations compromised bridge structure.

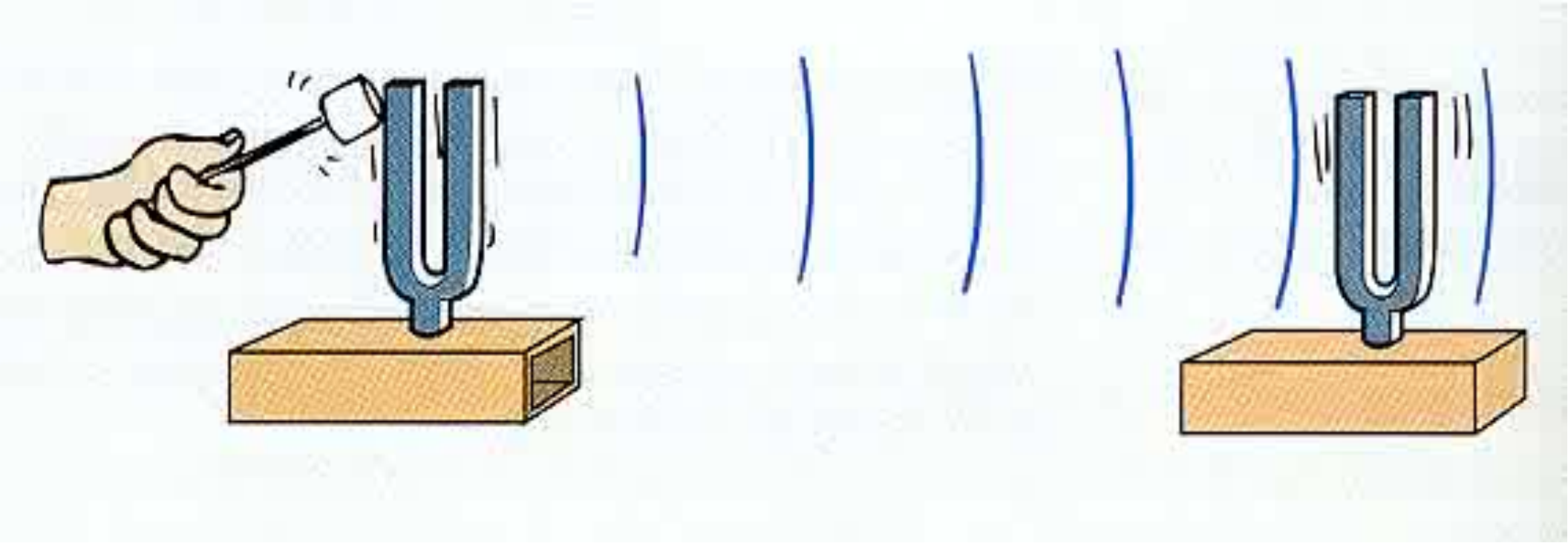
Tuning fork



Tuning fork

vibrations from first fork → sound waves → if frequency of second fork matches first one → forced vibrations with appreciable amplitude (friction kills much of the transmitted energy)

Tuning fork - demonstrations

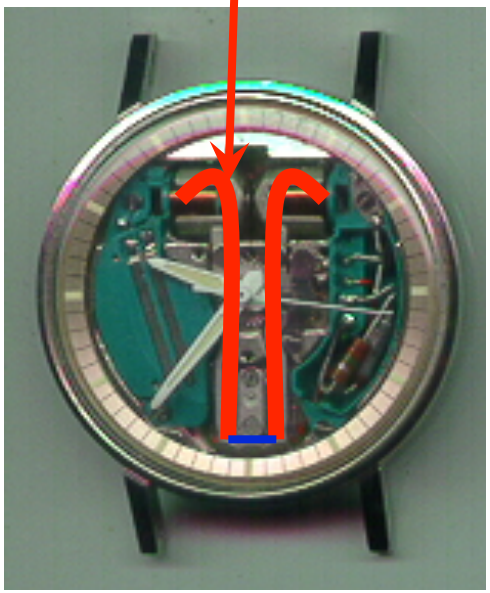


Tuning fork

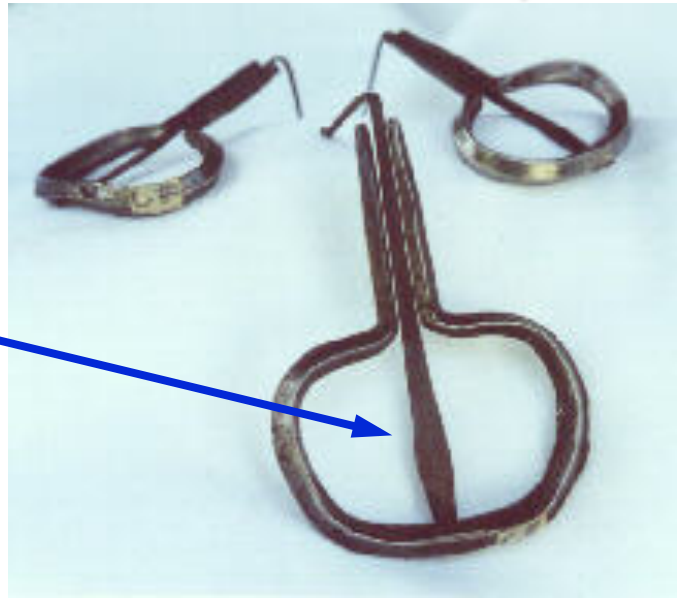
vibrations from first fork → sound waves → if frequency of second fork matches first one → forced vibrations with appreciable amplitude (friction kills much of the transmitted energy)

Simple Harmonic Oscillators producing sounds

Tuning Fork
(Bulova Accutron)



Mouth Harp



Oscillator

Kalimba
(Finger Piano)

Simple Harmonic Oscillators producing sounds

Harmonica ("Mouth Organ")

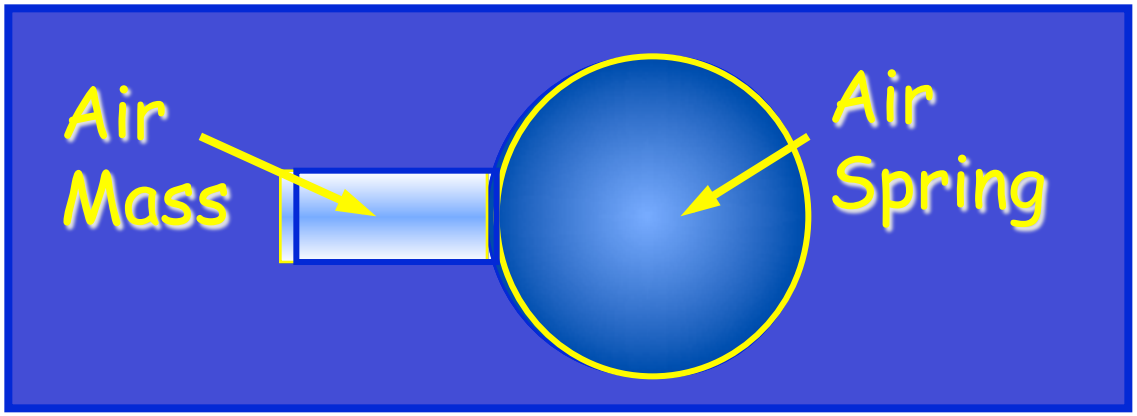
Helmholtz Resonator

Hermann von Helmholtz (1821-1894)

Prominent 19th century physicist and mathematician.

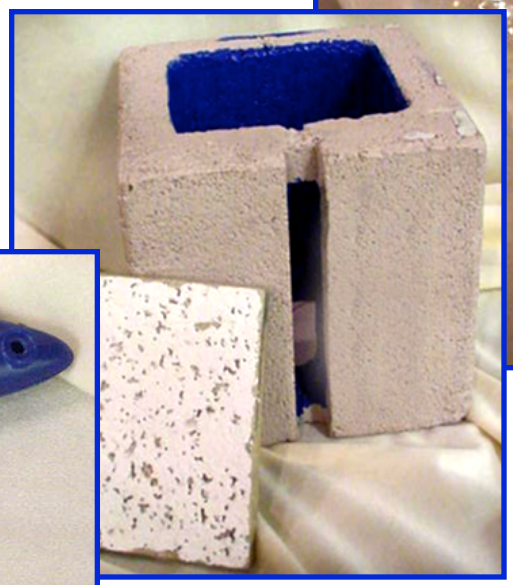
Author of **Perception of Tone**, highly influential treatise in musical acoustics.

A ***Helmholtz Resonator*** is a simple harmonic oscillator that uses air in a narrow neck as a mass and air trapped in a volume as a spring.



Examples:

- ***Bottle***
- ***Acoustic Tile***
- ***Cinder Block***
- ***Ocarina***



Helmholtz Resonator

- Ocarina