Exploring wave physics with sound

23 October 2017
Second Workshop on «Science Dissemination for the Disabled»

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- Introduction

- Part 1: speed of sound
- Part 2: interference
- Part 3: beats

- Conclusions

The proposal

«The choice of sound comes from the pervasiveness of the acoustic experience in everyday life, which is true also for light, but the wave nature of sound is more direct than that of light (i.e.: Doppler's Effect)»

Pros & cons

- Low cost
- It can be too noisy for near-by classrooms

Accessible science

- These experiments could be useful for students with sight conditions
- Care is required when students with hearing impairment are involved

Target

- High school teachers
- Italian high school students aged 15-18

Indicazioni Nazionali, Ministero dell'Istruzione, dell'Università e della Ricerca, http://www.indire.it/lucabas/lkmw_file/licei2010/indicazioni_nuovo_impaginato/_Liceo%20scientifico.pdf, 2010, read on 25 May 2017

Preconceived notions

- Sound is thought of as a particle-like entity that moves through bodies;
- Sound and waves are thought of as moving mass
- Lack of consistency in describing waves
- Materials are sometimes seen as an impediment to sound propagation
- Mistakes in the roles of elasticity, tension, density

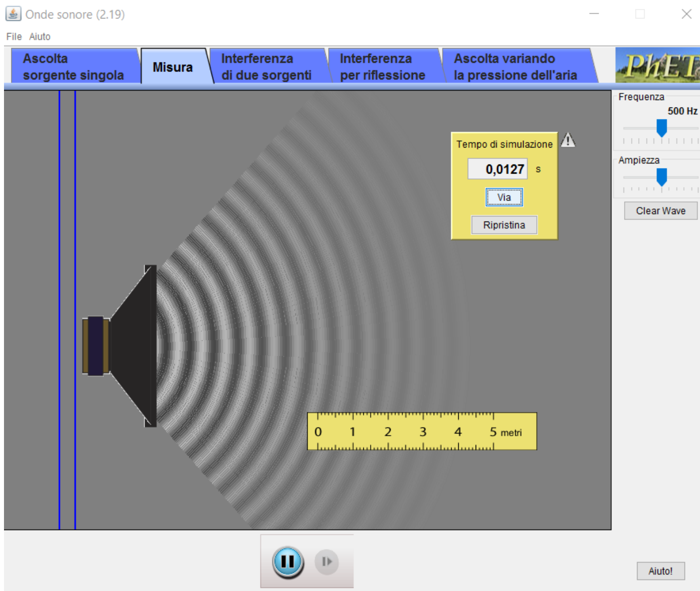
Fazio C., Guastella I., Sperandeo-Mineo R. M., Tarantino G., *Modelling Mechanical Wave Propagation: Guidelines and experimentation of a teaching-learning sequence*, International Journal of Science Education,Vol. 0, No. 11, 3 settembre 2008, pagg. 1491-1530

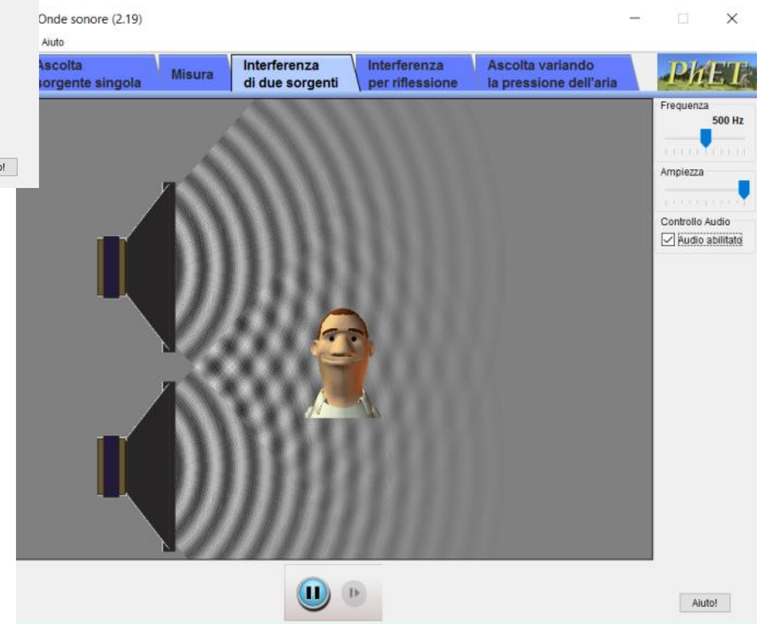
Goals

- Highlight longitudinal waves;
- Solve some misconceptions;
- Promote interchange between theory and experiment;
- Promote laboratory experience;
- Provide a low-cost solution;
- Stress the importance of inclusion.

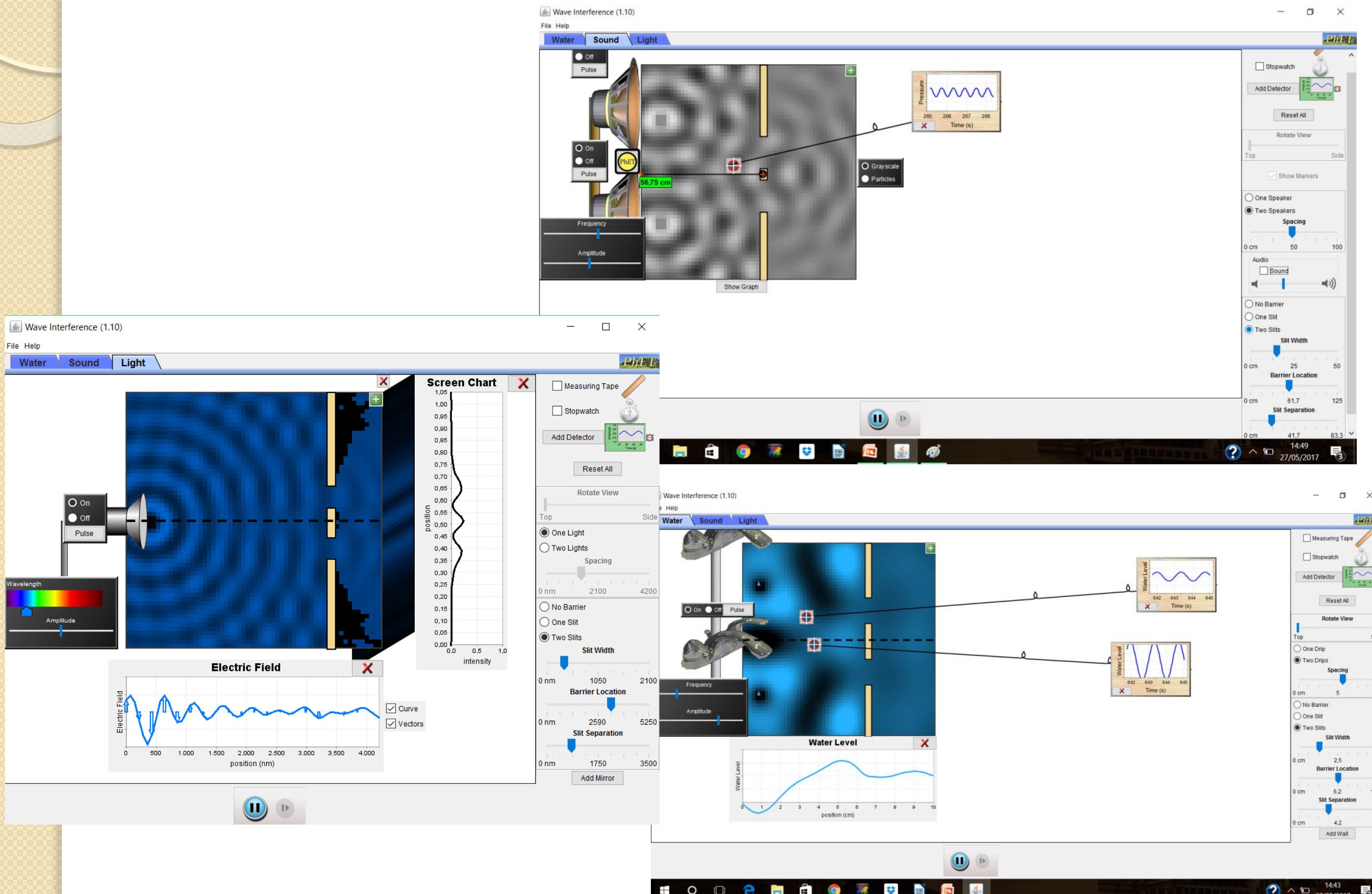
Applet

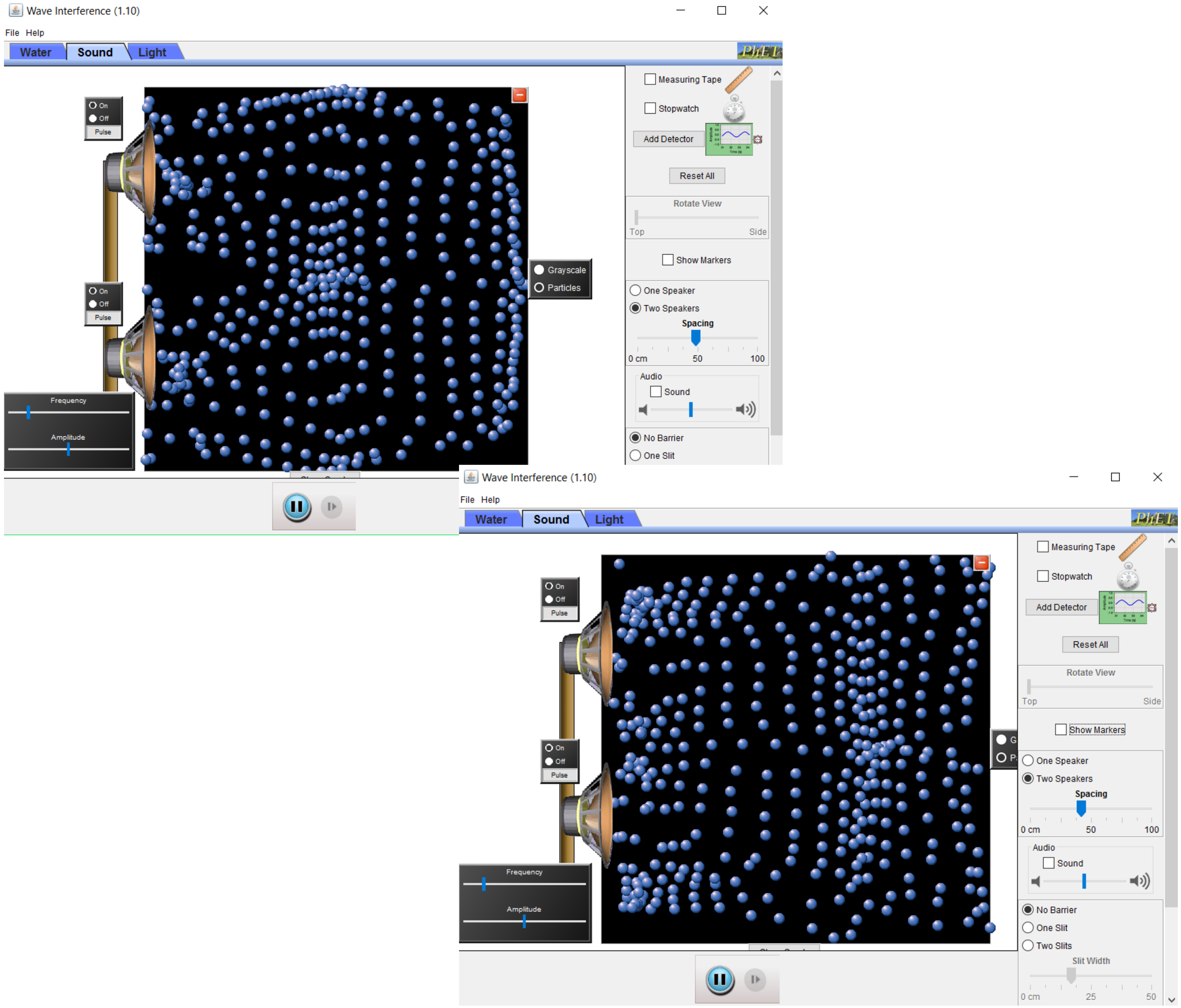
1. Sound





2. Wave Interference




Wave Interference (1.10)
File Help
Water
Sound
Light
PhET
On
Off
Pulse
Frequency
Amplitude
Grayscale
Particles
Measuring Tape
Stopwatch
Add Detector
Reset All
Rotate View
Top
Side
Show Markers
One Speaker
Two Speakers
Spacing
0 cm
50
100
Audio
Sound
No Barrier
One Slit
Two Slits
Slit Width
0 cm
25
50

Part 1: Speed of Sound

Goal:

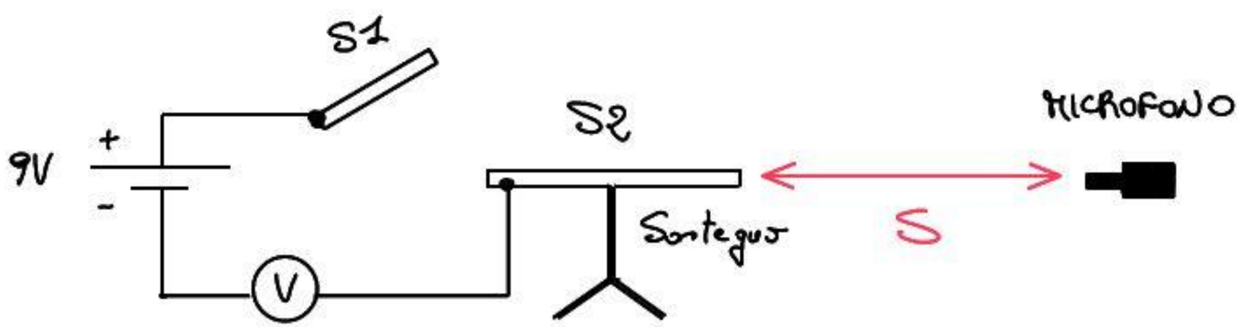
Measure the speed of sound in air and metals.

- The following part is taken from LEPLA (http://www.lepla.edu.pl/it/modules.php?name=Activities&file=m32).

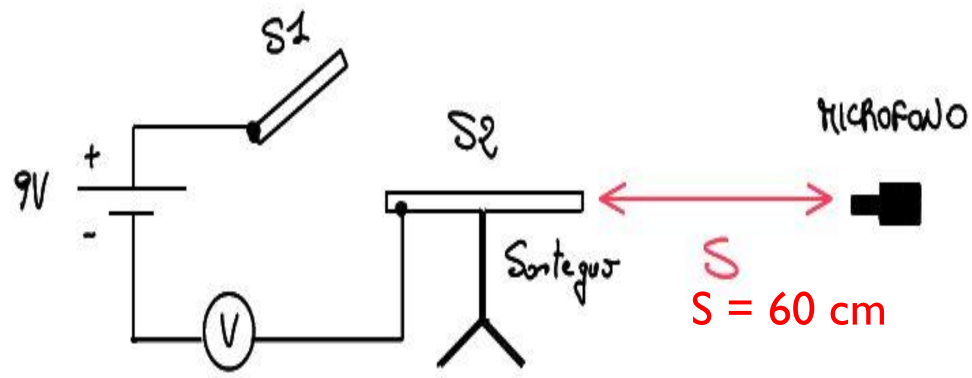
- The teacher builds a circuit with a voltmeter, a battery and two metal rods. A microphone is placed at a distance S from the rods.
- By hitting a rod with the other one, we close the circuit and measure a voltage. The sound produced is measured by the microphone after a time Δt.

- Sound speed is then given by

$$c_s = \frac{S}{Dt}$$



1. Set-up: air

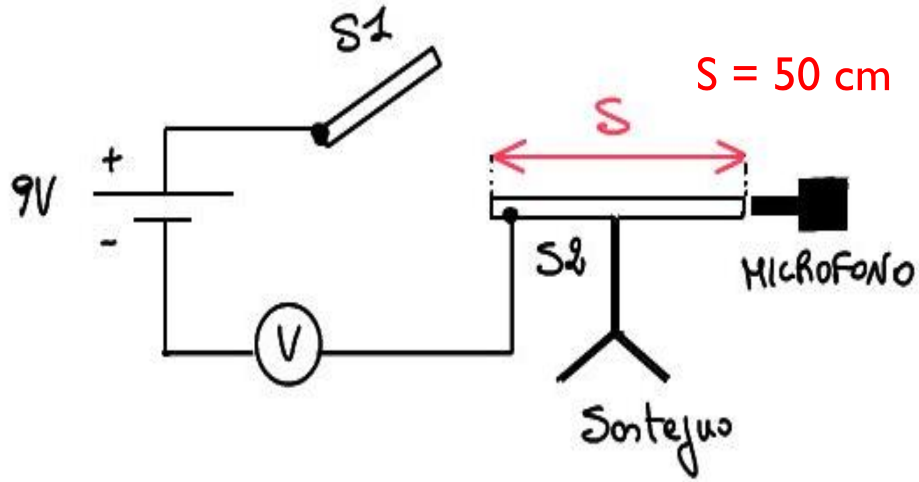


S = 60 cm

<u>Warning</u>:

- **Test the circuit**
- **Test the microphone**
- **<u>Misleading image:</u>** S2 rod is not parallel to S

2. Set-up: metal

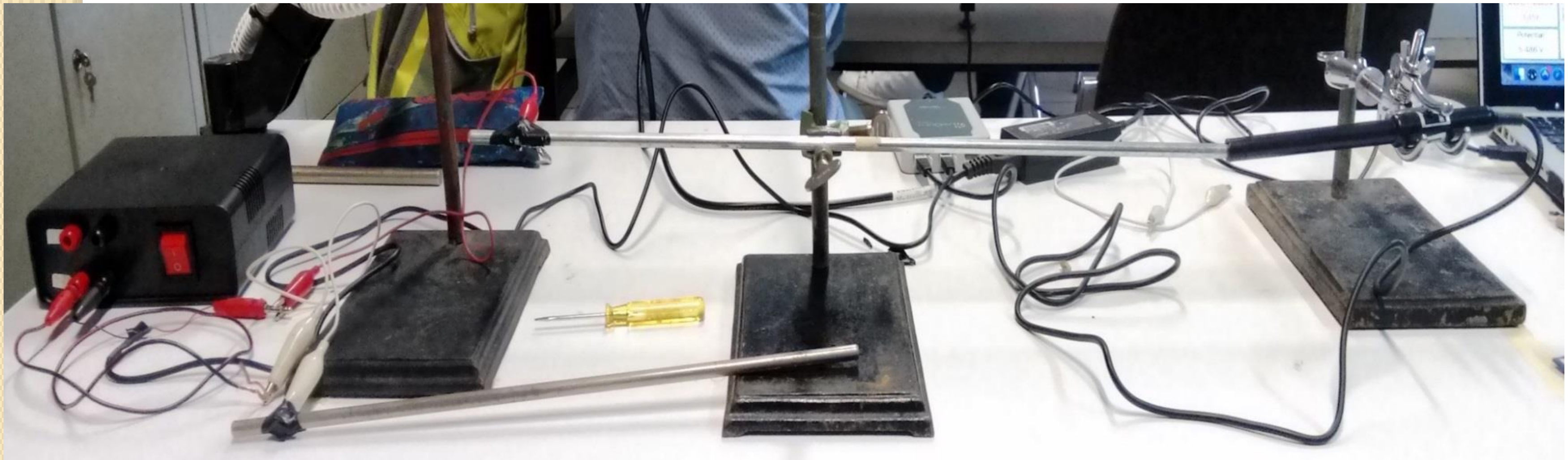


S = 50 cm

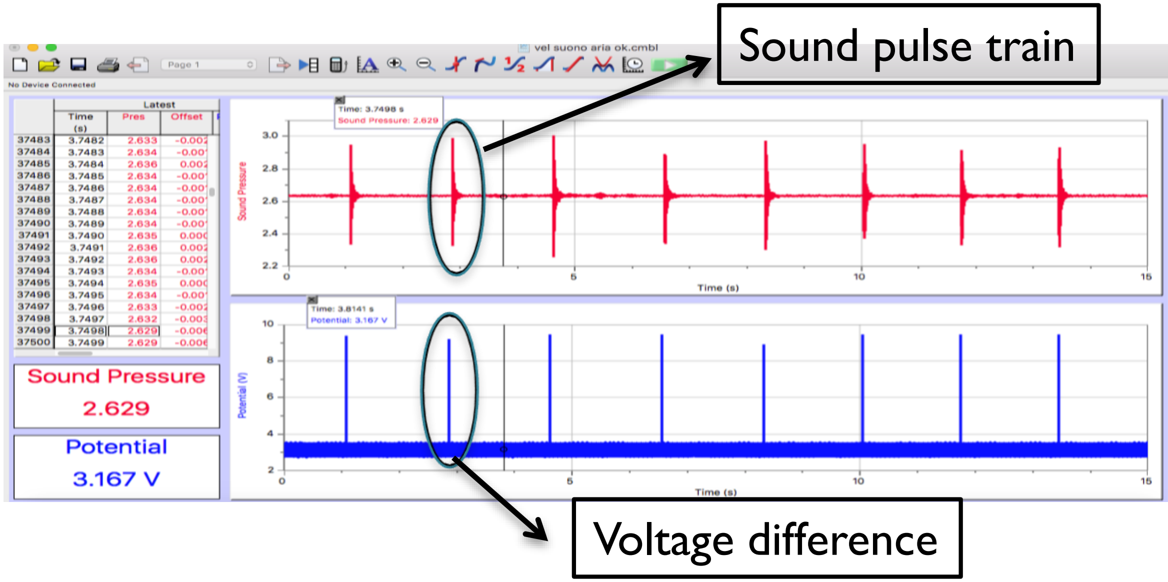
<u>Warning: minimize distance between rod and microphone.</u>

Measuring in air

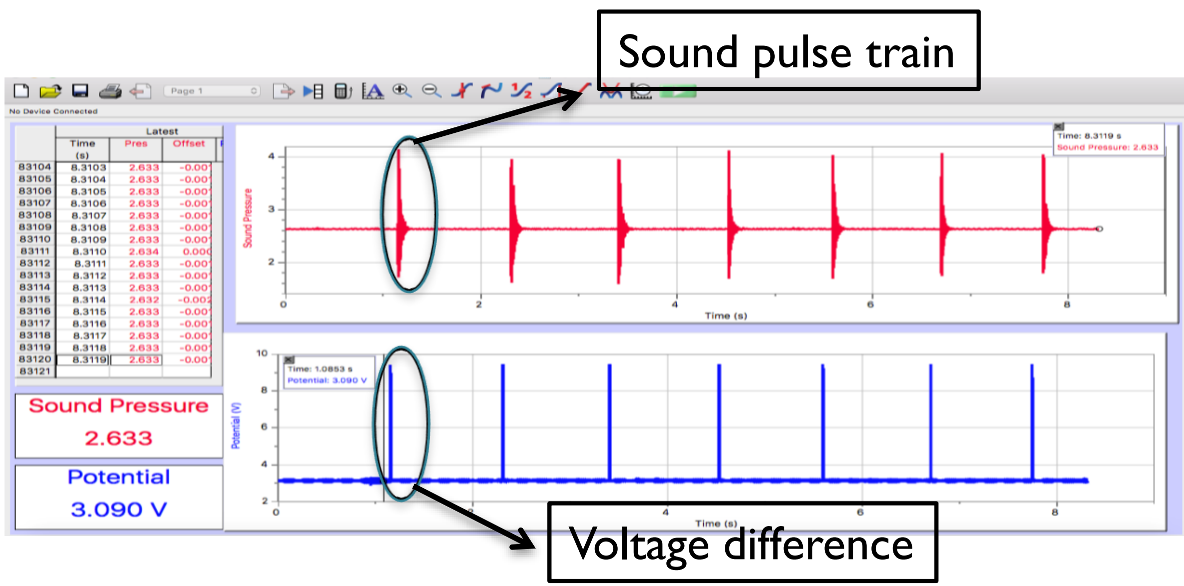
Measuring in metal



2. Data acquisition



Air

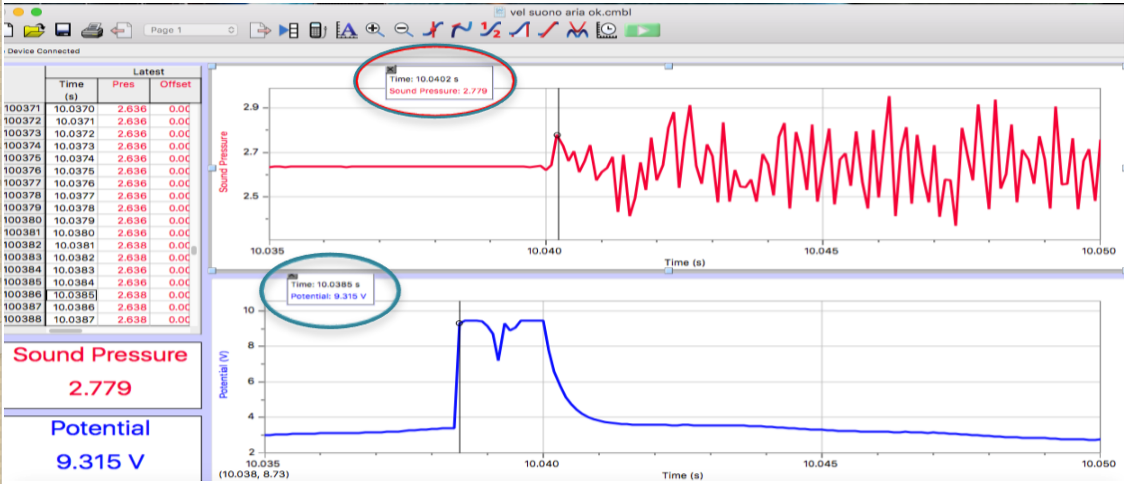


Metal

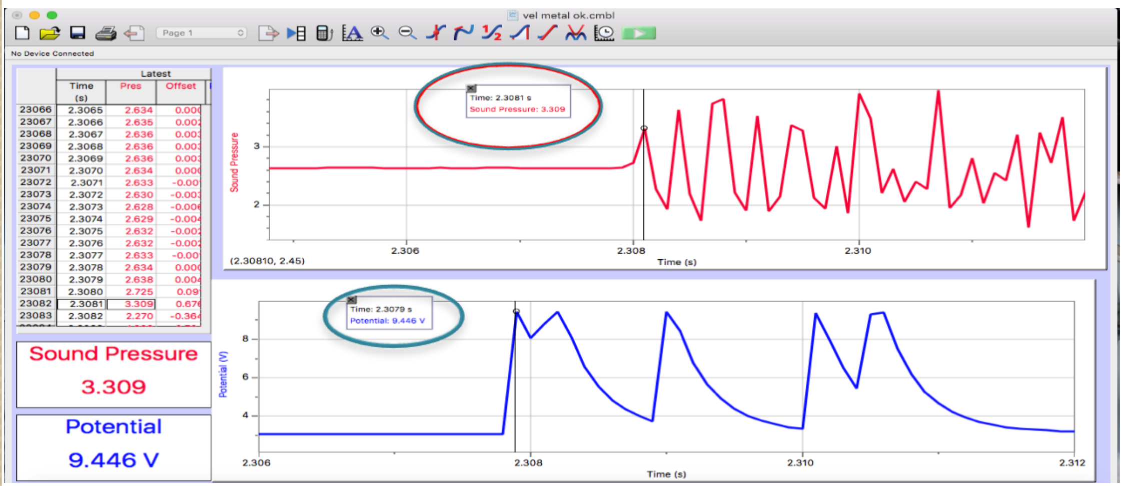
Data analysis

- t_0 voltage peak.
- t_1 pressure peak.

$$Dt = t_1 - t_0$$



Air



Metal

Warning: strong dependence on peak choice.

Air

t_0 (s)	t_1 (s)	Δt (s)
1,0845	1,0863	0,0018
2,8625	2,8643	0,0018
4,6189	4,6205	0,0016
6,5610	6,5627	0,0017
8,3210	8,3207	0,0017
10,0385	10,0402	0,0017
11,7419	11,7436	0,0017
13,4464	13,4481	0,0017

$$C_s = (3{,}5 \pm 0{,}1)\ 10^2\ m/s$$

Acceptable value for air at 30°C

Metal

t_0 (s)	t_1 (s)	Δt (s)
1,1536	1,1537	0,0001
2,3079	2,3081	0,0002
3,4040	3,4041	0,0001
4,5253	4,5254	0,0001
5,5899	5,5901	0,0002
6,7003	6,7005	0,0002

Acceptable value for steel

$$C_s = (3{,}8 \pm 1{,}2)\ 10^3\ m/s$$

Nota: error calculation depends on the school class. Here STDEV has been used.

Final discussion & conclusions

- Did different groups reproduce the results when in the same conditions?

- Instrument resolution

- Compare the order of magnitudes between metals and air

Module 2: interference

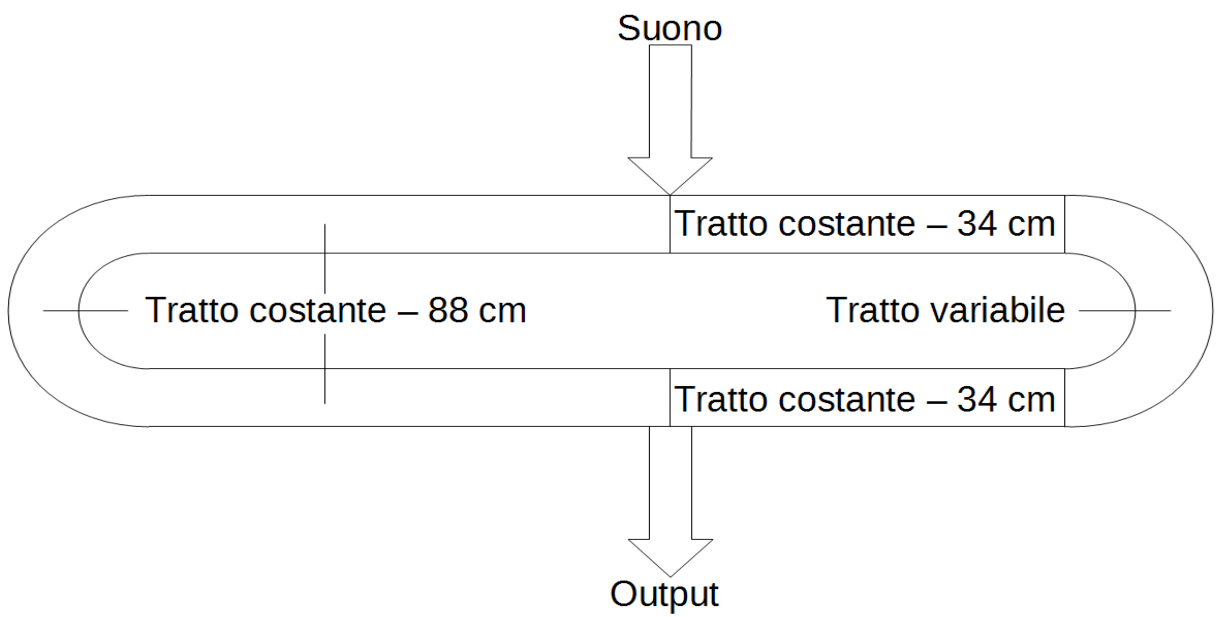
Prerequisites:

- Trigonometry
- Basic wave physics

Outline:

1. Quincke's tube
2. Young interference

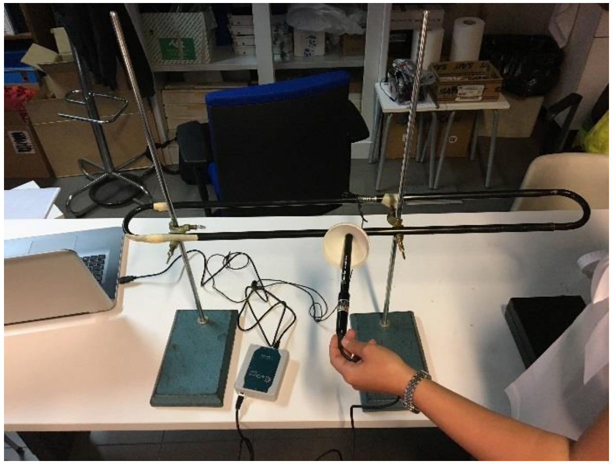
Quincke's Tube



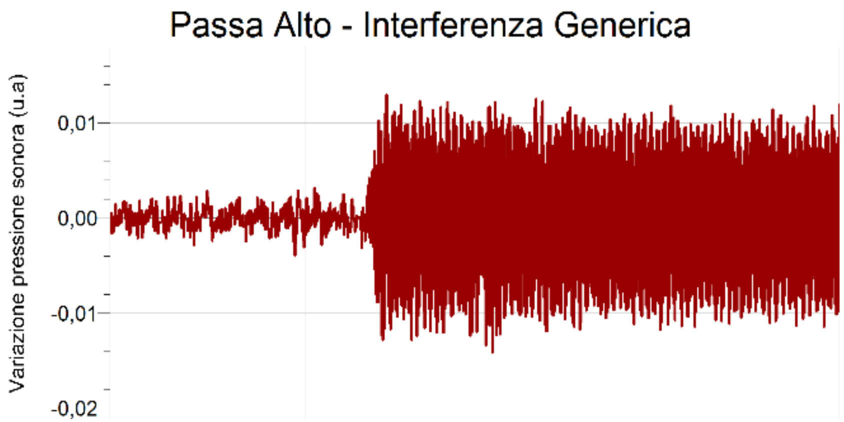
Vittorio Zanetti, *Teoria ed esperimenti di Fisica*, Zanichelli, cap. 21, pagg. 383-384, 1993

Set-Up

- A set of tubes
- Stands
- Sound generator
- Funnel
- Meter
- Microphone
- Computer



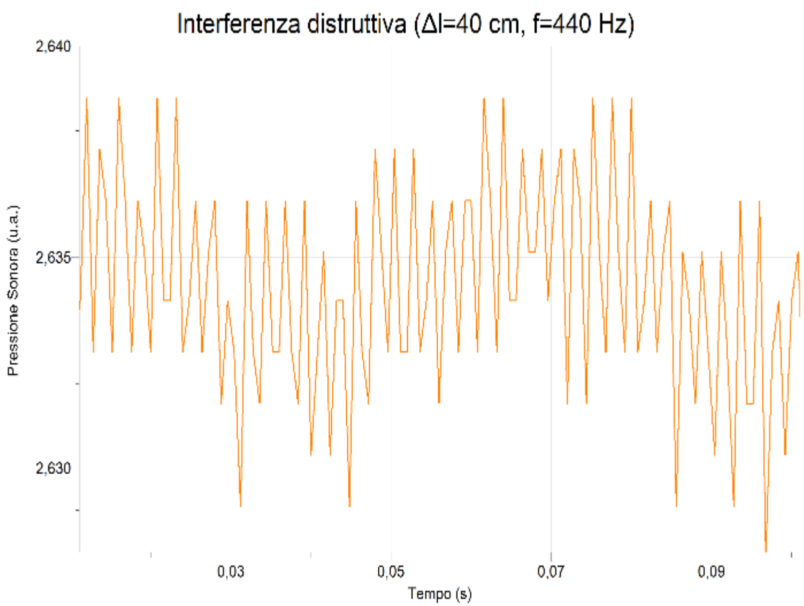
Results

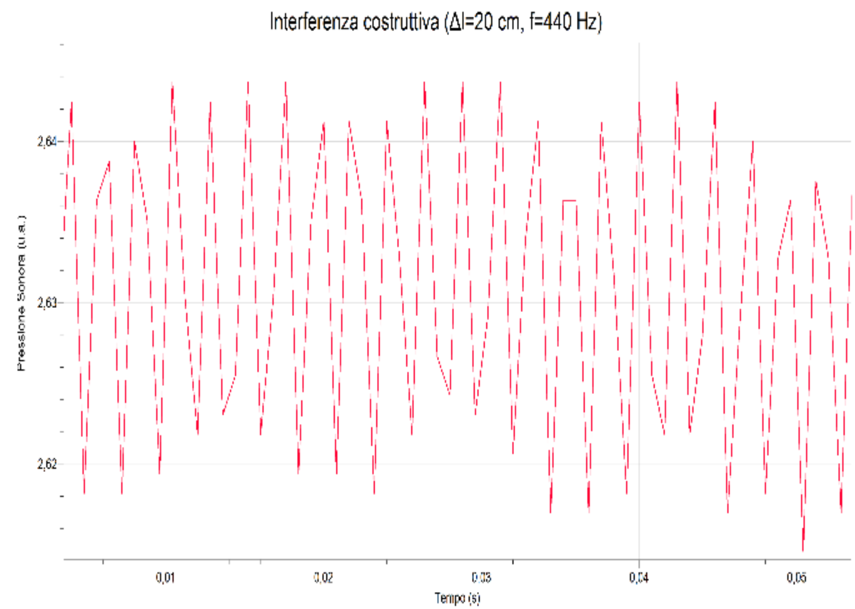


V=3.3 x10^2 m/s

Pressure Variation:

- Destructive interf.: 0.005 a.u.
- Constructive interf.: 0.02 a.u.
- Background: 0.001 a.u.





Conclusions

- This easy setup is useful for demonstrations;
- A finer control is needed when doing quantitative measurements;
- In that case, proper materials are adviced;
- Very clear constructive interference;
- Good for understanding the role of errors and real world/theory differences;
- Trade-offs are:
  1. Low intensity *vs* external noise
  2. *Black-box* HPF *vs* frequency-domain analysis

Young's Interference[1,2]

- 2 loudspeakers separated by 50 cm
- Signal generator @ 2000 Hz
- It has great historical importance
- It promotes teamwork
- It requires open spaces
- Quantitative measurements can be performed

1. *Episode 321: Interference patterns*, Institute of Physics, http://www.tap.iop.org/vibration/superpostion/321/page_46750.html, consultato il 25 maggio 2017
2. *Young's fringes with sound waves*, Institute of Physics & Nuffield Foundation, http://practicalphysics.org/youngs-fringes-sound-waves.html, 2014, consultato il 25 maggio 2017

Part 3: Beats

Goals:

- link theoretical concepts to experience;
- learn about the beats phenomenon;
- learn the use of a data analysis software.

Prerequisites

- Basic physical quantities of waves
- Understanding of interference

Set-up

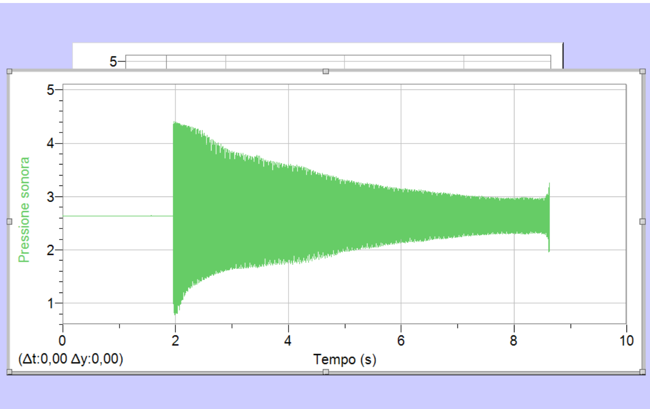
- 2 tuning forks
- A clamp
- A microphone
- DAQ software

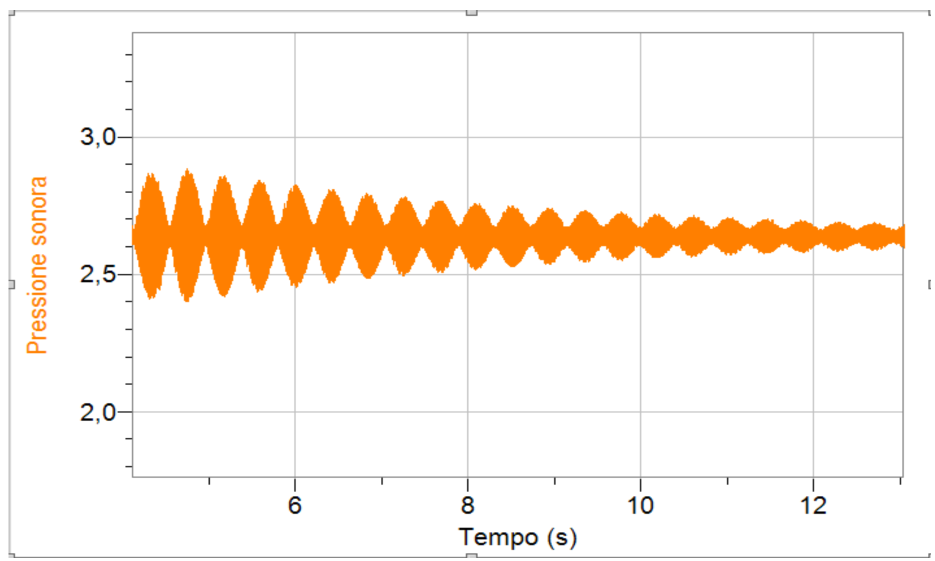
The experiment

1. Measure the frequency of the 2 tuning forks
2. Measure an unknown frequency
3. Produce beats
4. Measure beats frequency

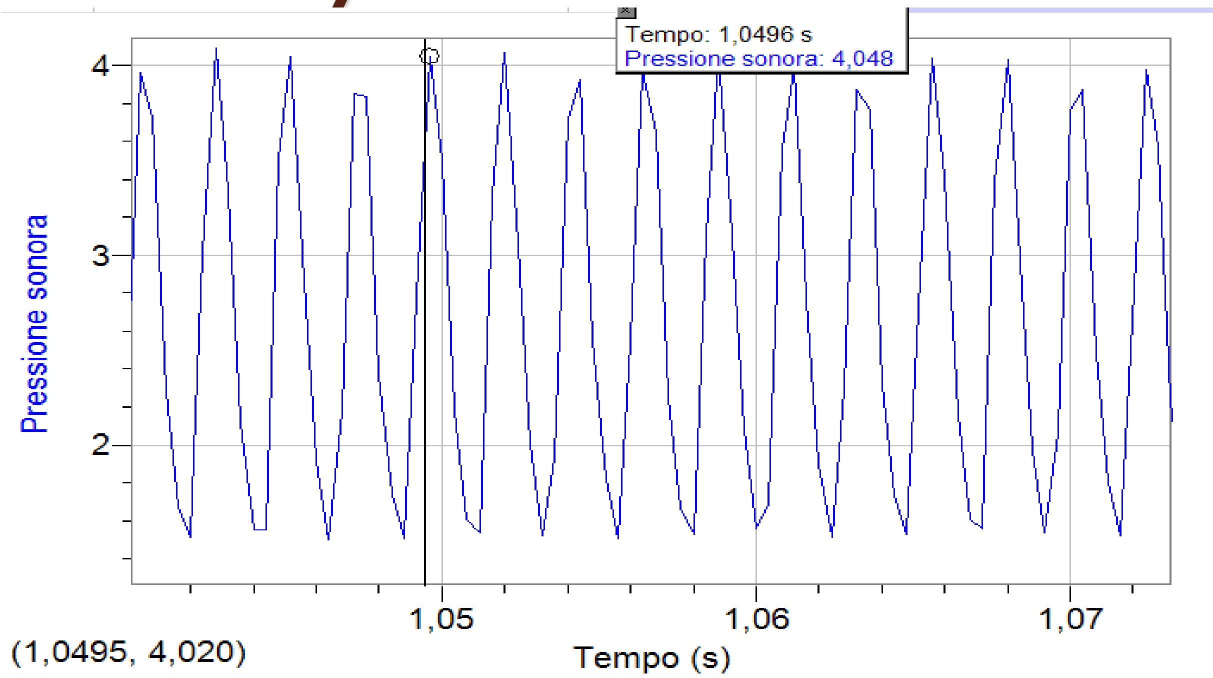
Data acquisition

	Set dati 1		
	Tempo (s)	Pres	Offset
1	0,0000	2,644	0,003
2	0,0016	2,635	-0,006
3	0,0032	2,634	-0,007
4	0,0048	2,635	-0,006
5	0,0064	2,633	-0,008
6	0,0080	2,633	-0,008
7	0,0096	2,634	-0,007
8	0,0112	2,633	-0,008
9	0,0128	2,633	-0,008
10	0,0144	2,634	-0,007
11	0,0160	2,633	-0,008
12	0,0176	2,634	-0,007
13	0,0192	2,633	-0,008
14	0,0208	2,634	-0,007
15	0,0224	2,634	-0,007
16	0,0240	2,634	-0,007
17	0,0256	2,635	-0,006
18	0,0272	2,633	-0,008
19	0,0288	2,636	-0,004
20	0,0304	2,635	-0,006
21	0,0320	2,638	-0,003





Data analysis



	f_1	f_2	$fb=\|f_1-f_2\|$
1	440,0 Hz	423,2 Hz	16,8 Hz
2	440,0 Hz	416,7 Hz	23,3 Hz
3	440,0 Hz	420,1 Hz	19,9 Hz

Conclusions

- Students can experience beats;
- Students learn and use frequency and period;

Final remarks

- Students see different ways to measure different physical quantities, and even the same ones;
- Longitudinal waves are shown;
- The first part addresses some common misconceptions is matter propagation with waves;
- Relevant physical phenomena are experienced by the students.

Final remarks 2

- DAQ system could be an issue to address
- The course has not been tested;
- Lots of room for improvement and low-cost solutions
- Also low-technology solution can provide quality education
- Flexibility

Thank you.