

Proposal for a didactic path on oscillations and waves for the secondary school:

the normal modes of oscillation.

Results of the preliminary experimentation

# main activities in the first year

- Construction of an experiments-based path on oscillations and waves in the framework of PLS activities
- Study of the harmonic and parametric motion of the mass-spring system via different data logging techniques
- Preliminary experimentation on teaching normal modes in the secondary school

# MOTIVATIONS

The physics education research group of the University of Milano is currently working at the construction of teaching/learning sequences regarding:

- Quantum physics
- Superconductivity
- Oscillations and waves

We think that the approach with normal modes has a great importance for the understanding of all these topics

The topic is suitable both for a phenomenological and an experimental approach

# STATE OF THE ART

In the italian high schools normal modes are not commonly treated

Most of the italian physics textbooks for high school don't even have the topic

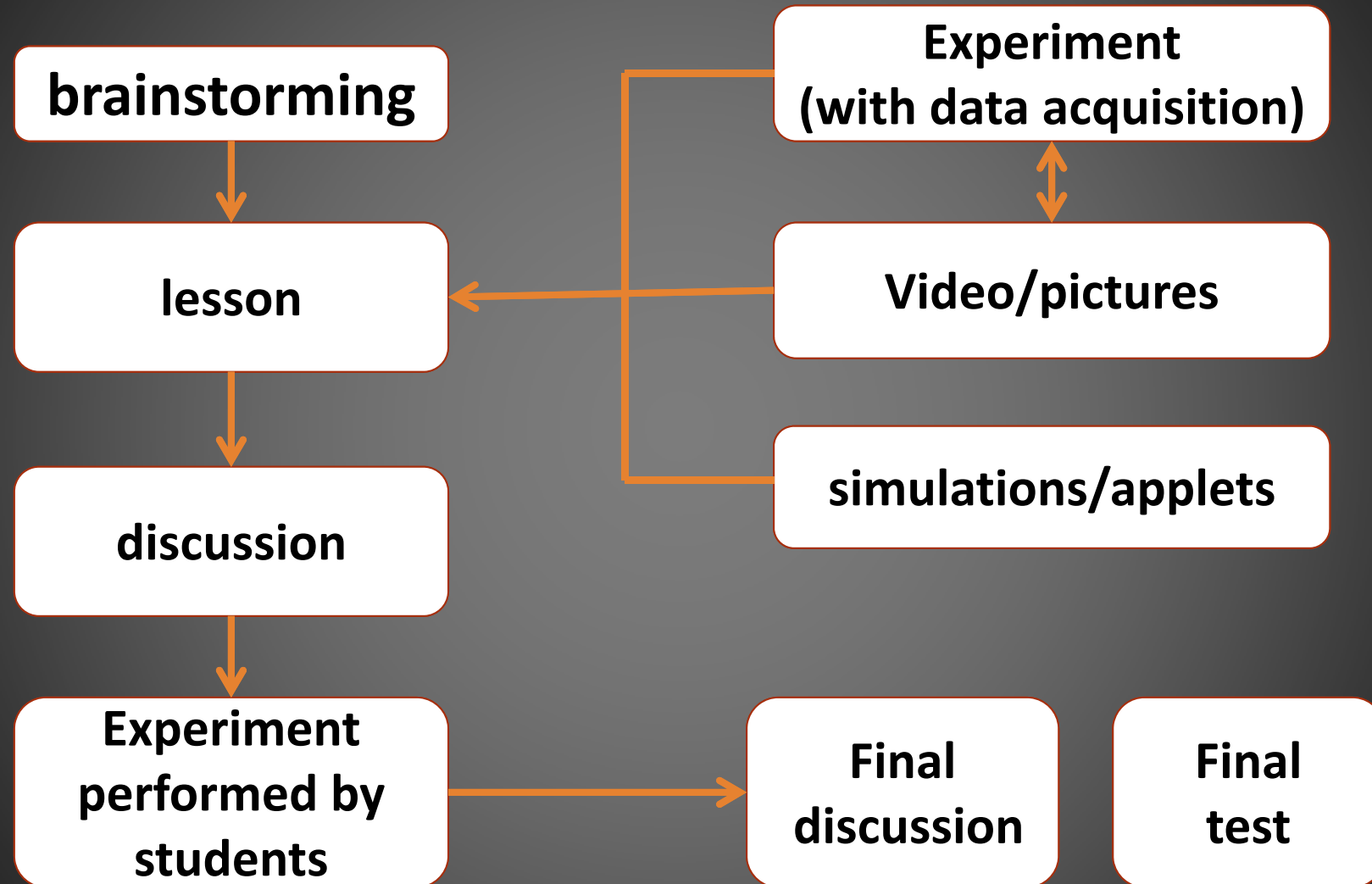
In literature it is difficult to find but few examples of teaching of normal modes to high school students, especially with an analysis of disciplinary knots and learning problems

# THE CONTEXT IN WHICH WE OPERATED

- The path on normal modes has been proposed to two different groups of students:
  - About 30 students participating to the extracurricular laboratories of the PLS together with 12 of their teachers
  - A class of 19 language school students during curricular lessons

- PLS students:
  - Attending 4th/5th year scientific school
  - Well trained in trigonometry
  - Some trained in basic calculus
  - Already studied topics on waves
  
- Curricular students:
  - Attending 4th year language school
  - Lack of knowledge in trigonometry
  - No basic calculus
  - Never studied topics on waves

# THE TEACHING/LEARNING SEQUENCE



# THE TOPICS

- the harmonic oscillator
- Coupled oscillators
  - Mass-spring systems
  - Coupled pendululums
- Normal modes, resonance and superposition principle
- The Shive wave machine
- The string (continuum)
- Normal modes in two dimensions



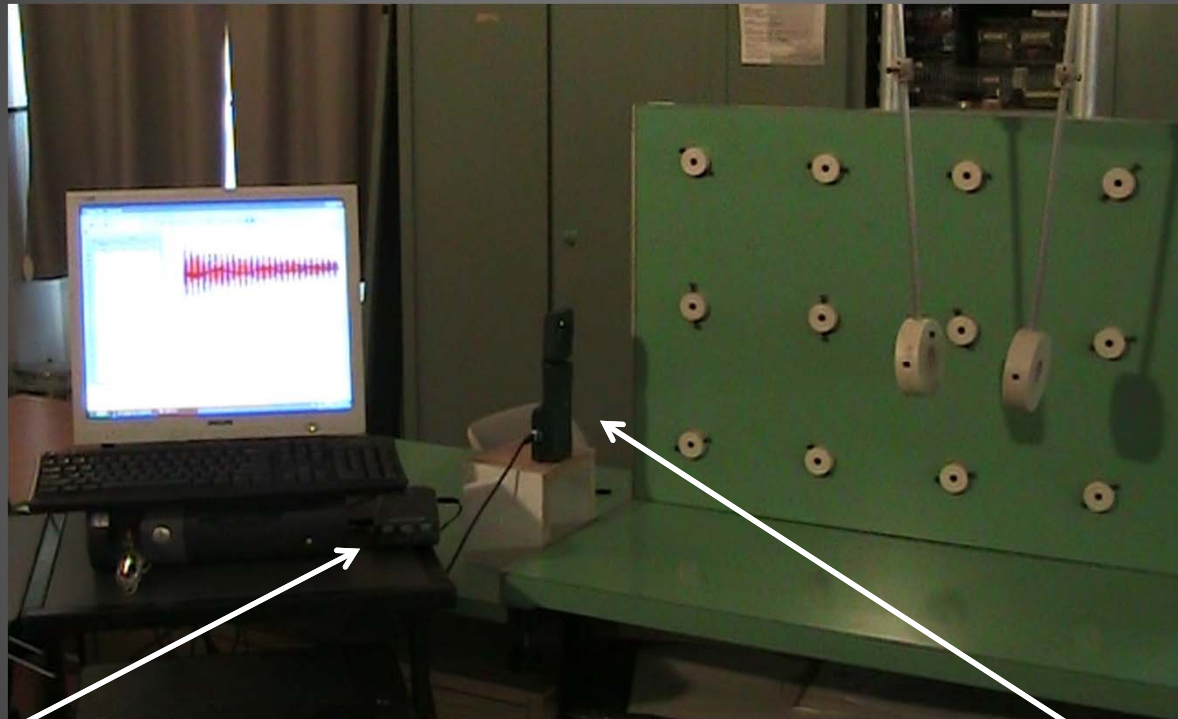


# SOME SIGNIFICATIVE EXPERIMENTS

From harmonic oscillations to normal modes of complex systems

2012 October 15

# THE EXPERIMENTAL SETUP



LoggerPro interface

Motion detector (sonar)

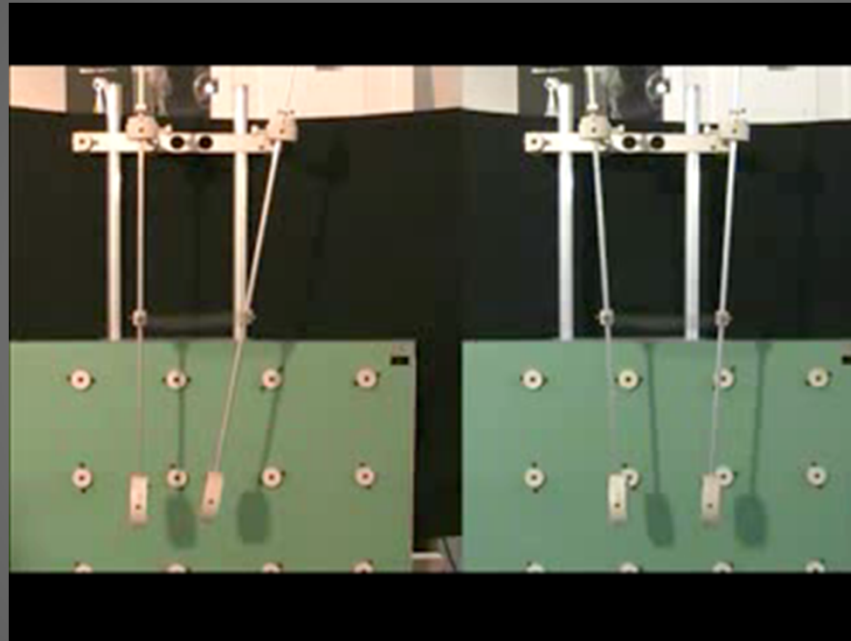
# THE SIMPLE HARMONIC OSCILLATOR



2012 October 15

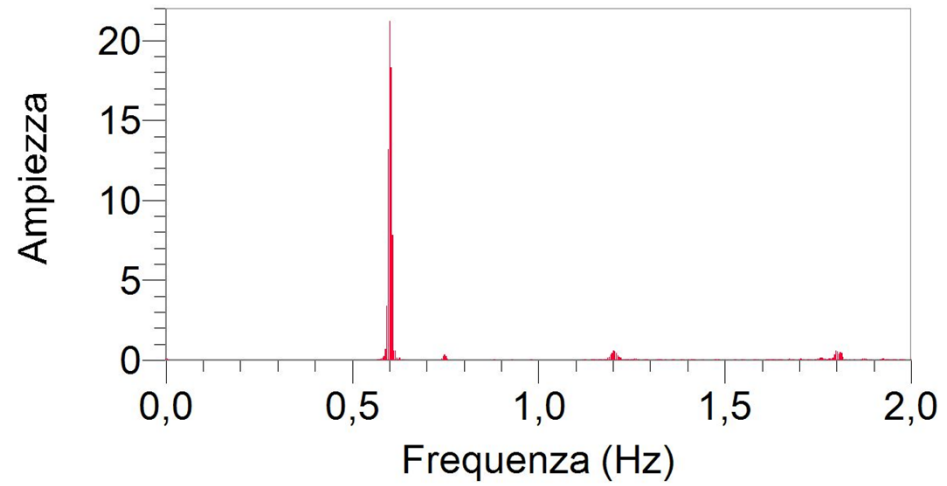
# TWO COUPLED PENDULUMS

First normal  
mode



Second normal  
mode

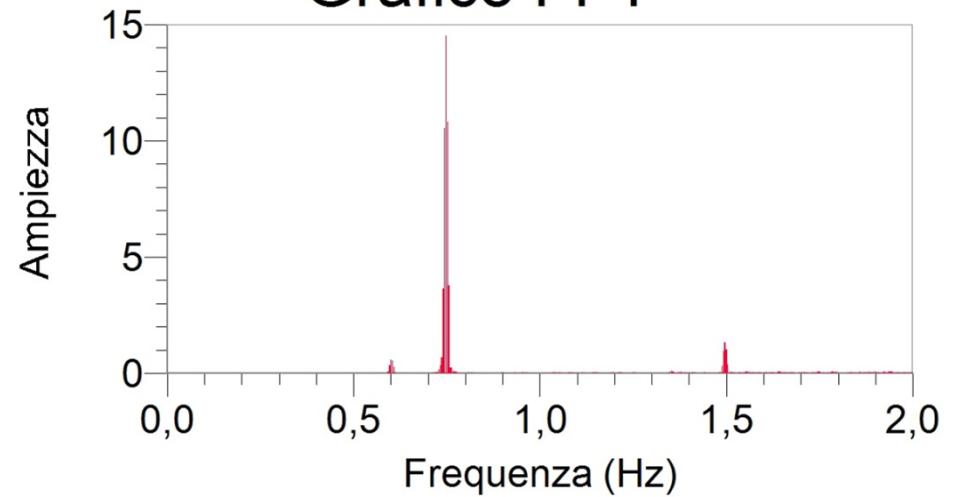
### Grafico FFT



First mode frequency

Second mode frequency

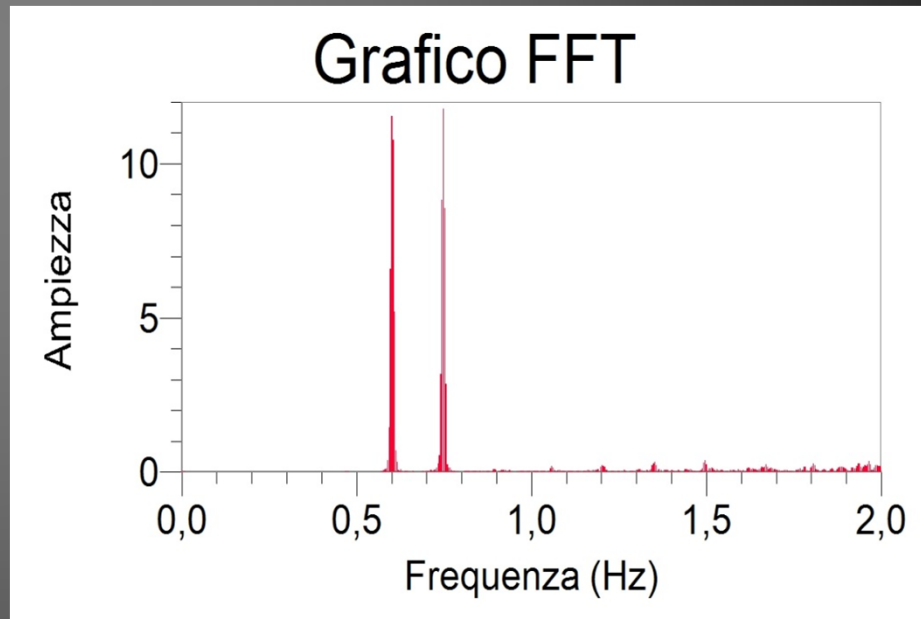
### Grafico FFT



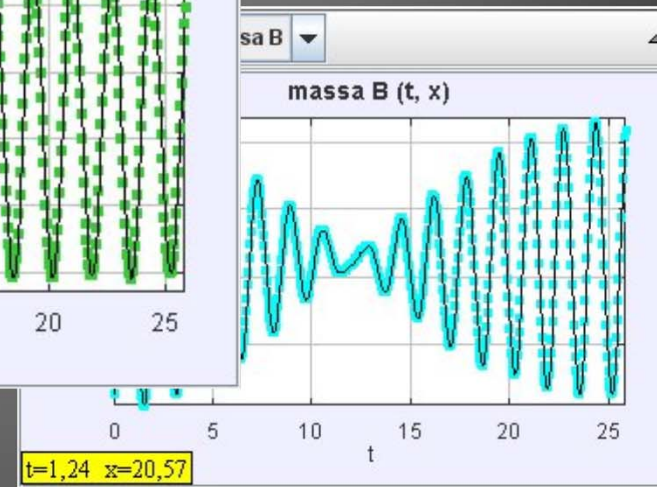
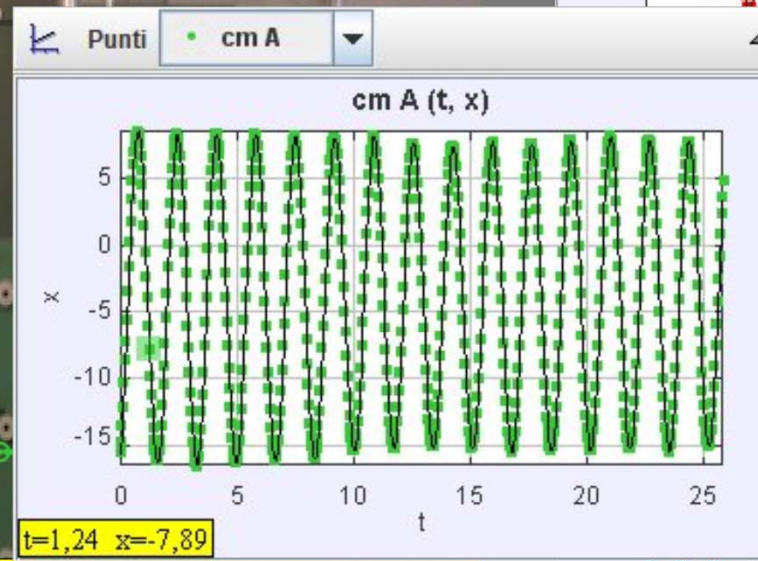
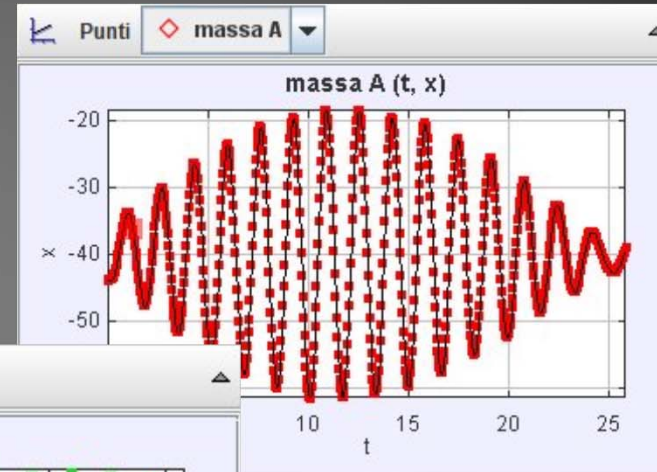
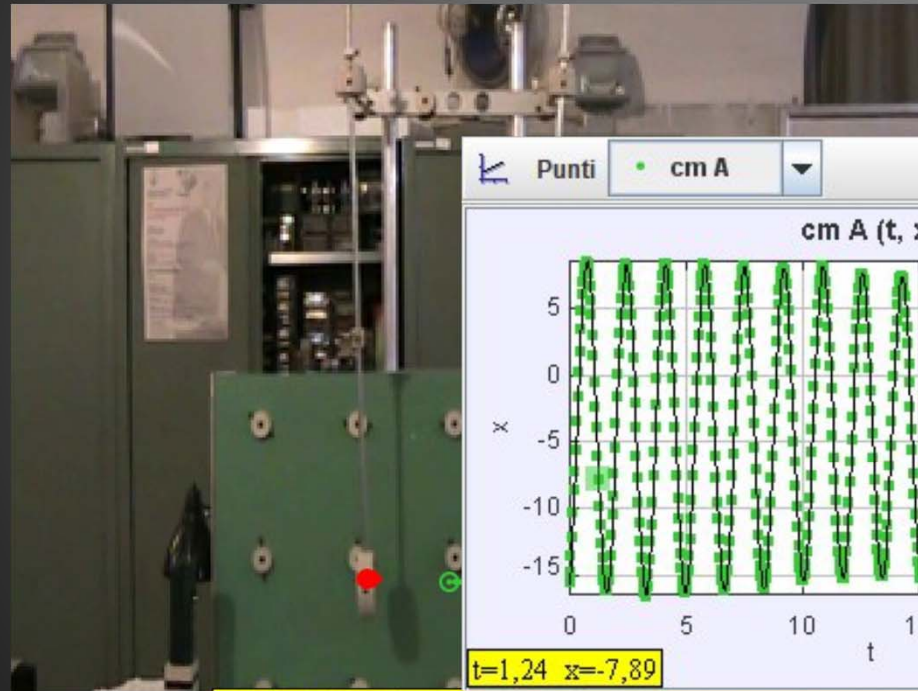
# Modes superposition



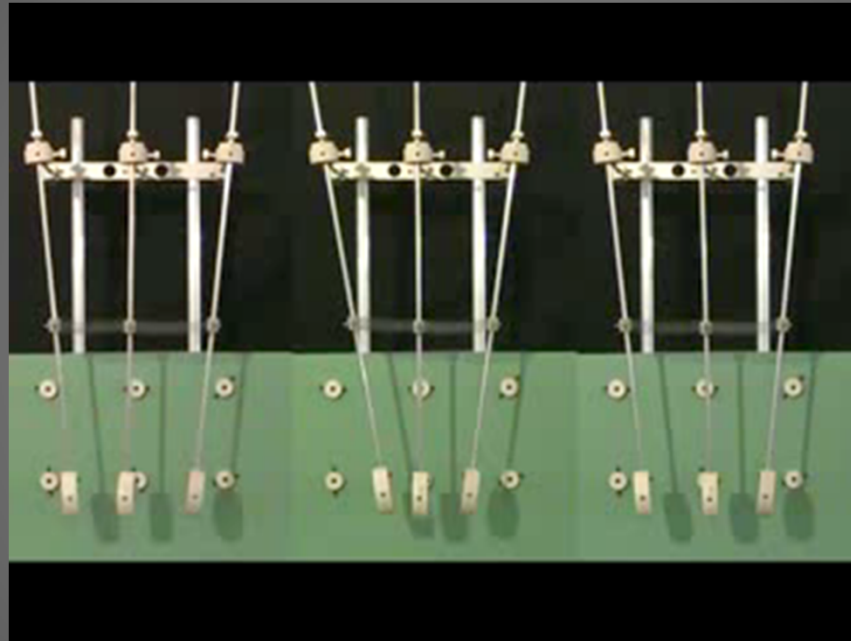
The superposition principle at work



# Video data logging (tracking)

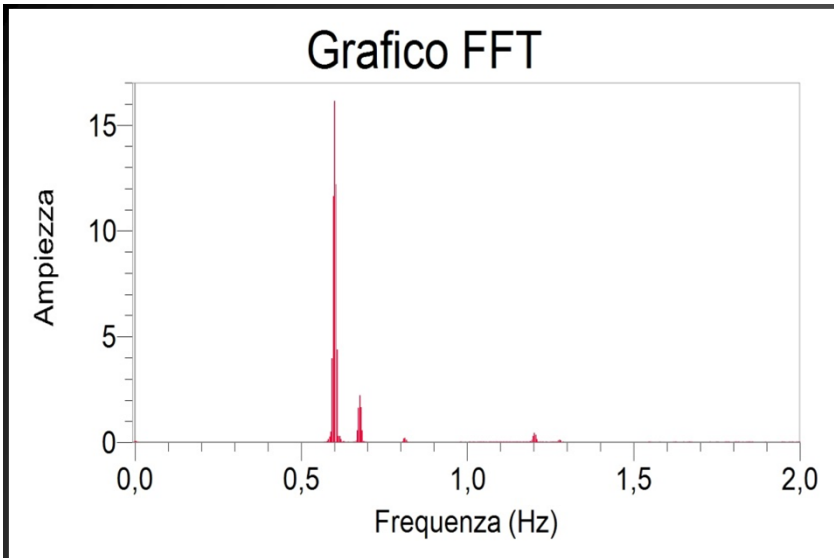


# THREE COUPLED PENDULUMS



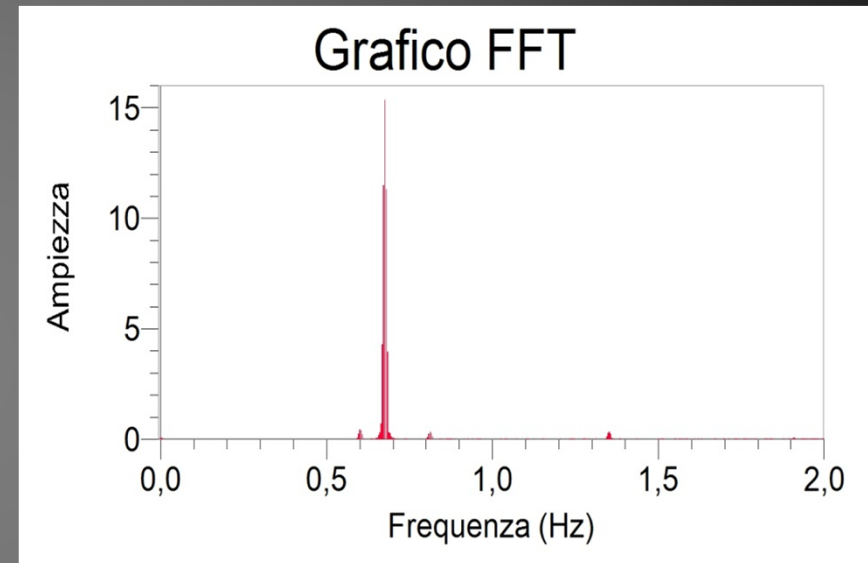
2012 October 15



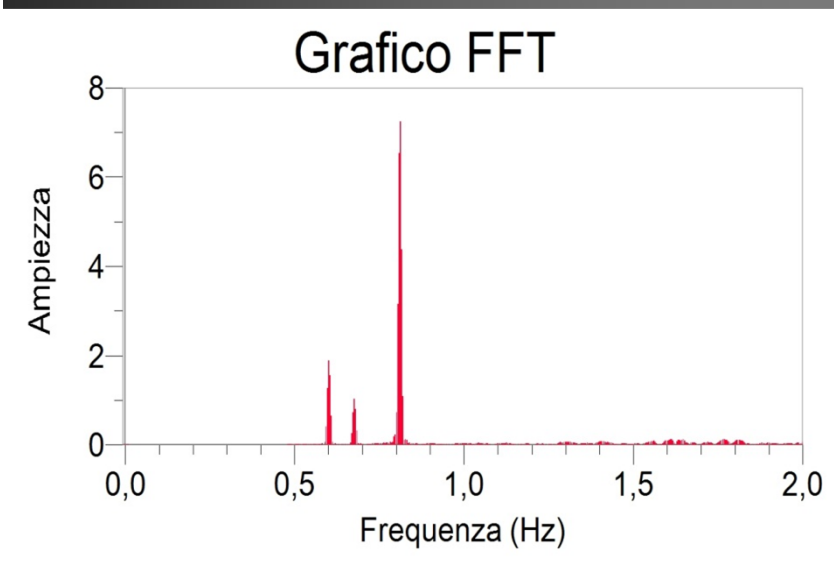


First mode frequency

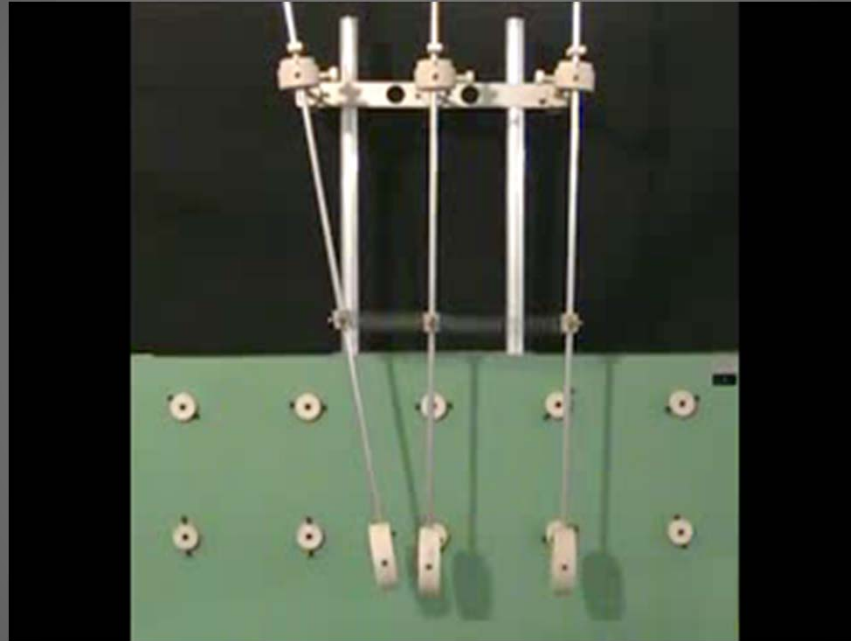
Second mode frequency



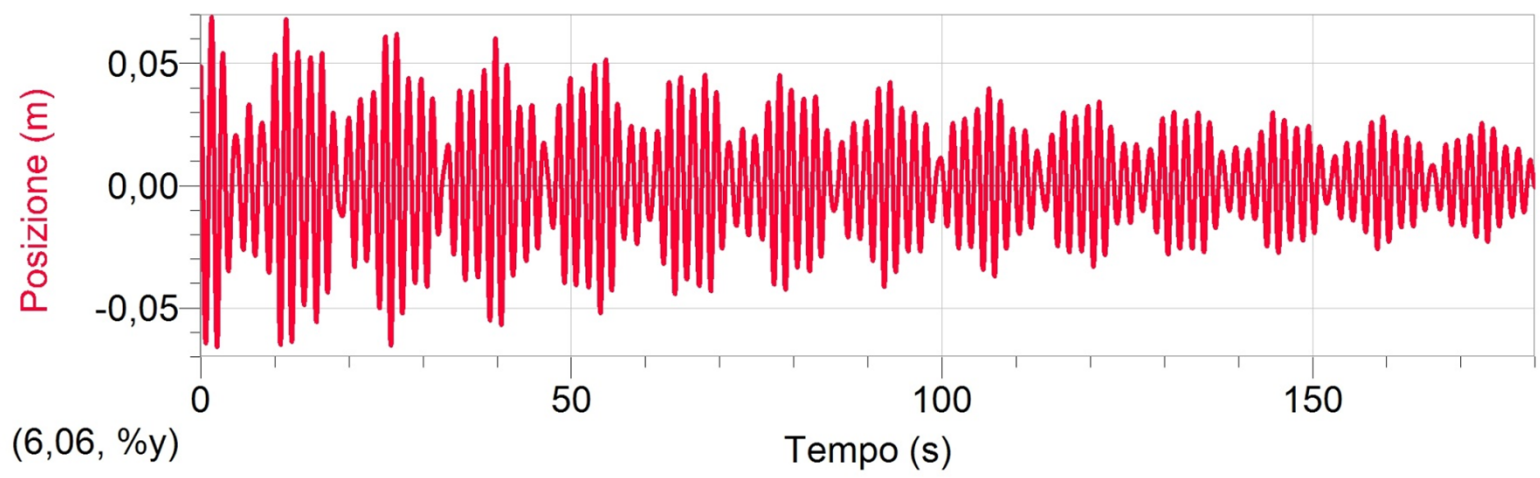
Third mode frequency



# Modes superposition



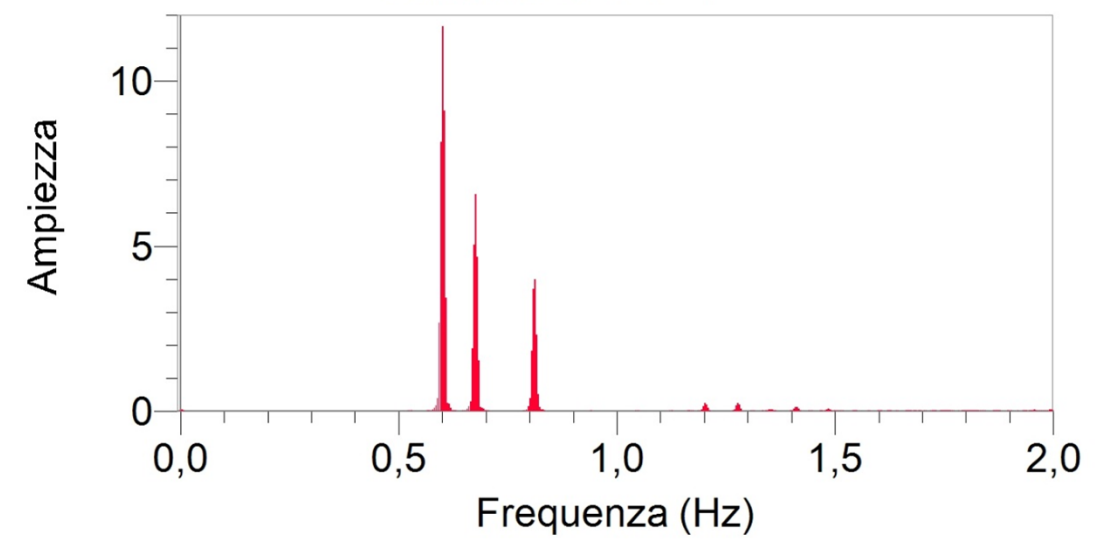
2012 October 15



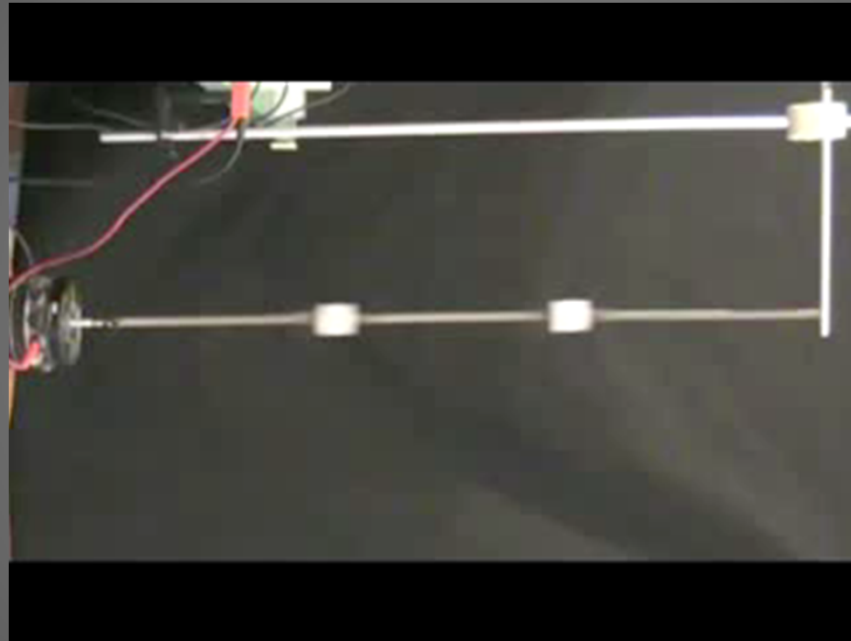
Beats

Again the superpositio principle at work

### Grafico FFT

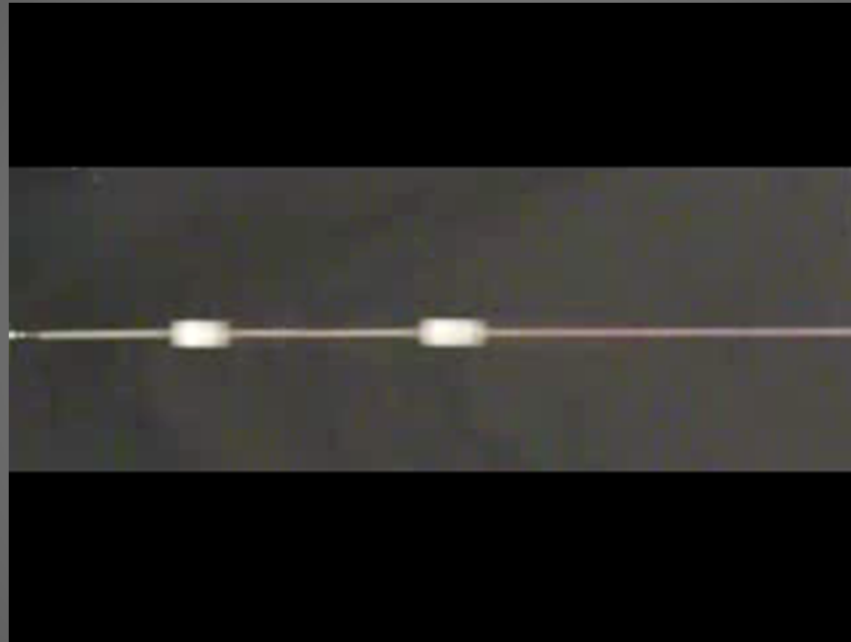


# MASS-SPRING SYSTEM



2012 October 15

# In slow motion



2012 October 15

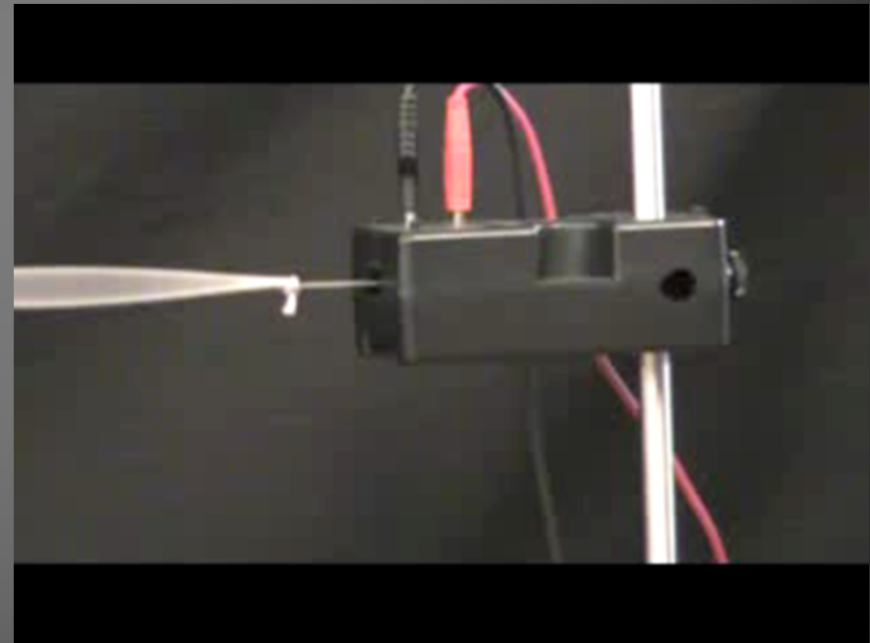
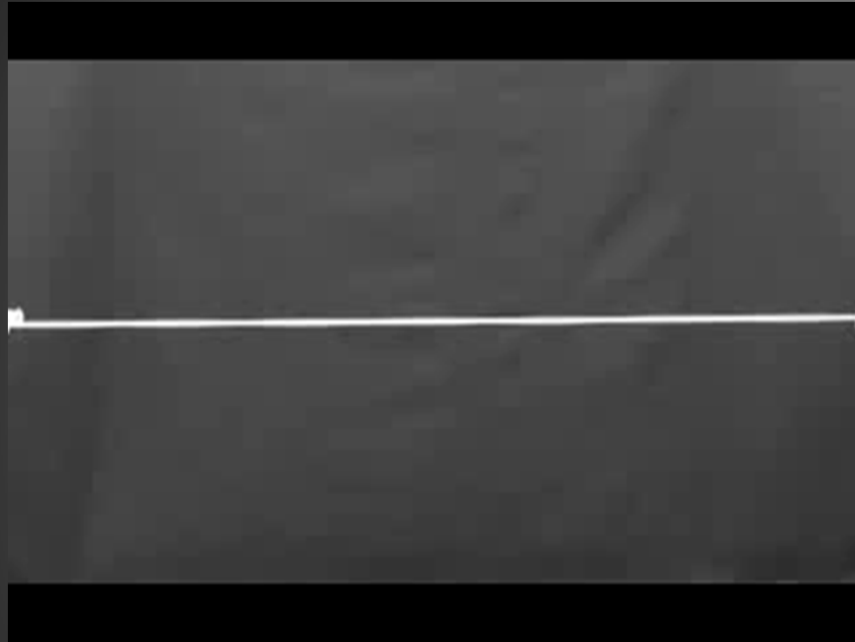
# Many coupled oscillators: the Shive machine

First mode



Second mode

# TRANSITION TO CONTINUOUS: THE STRING



2012 October 15

# Excitation of the first two modes



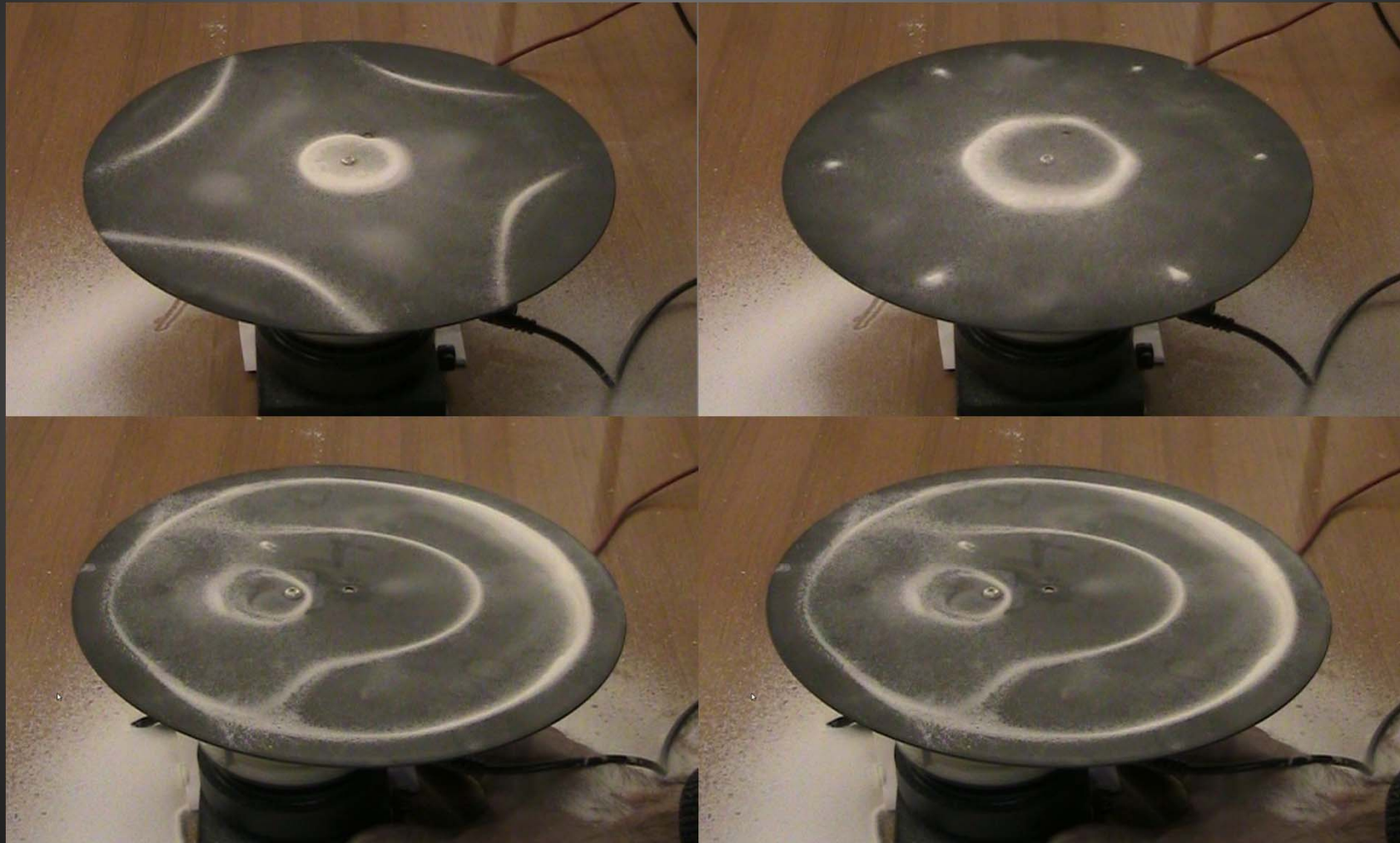
First mode



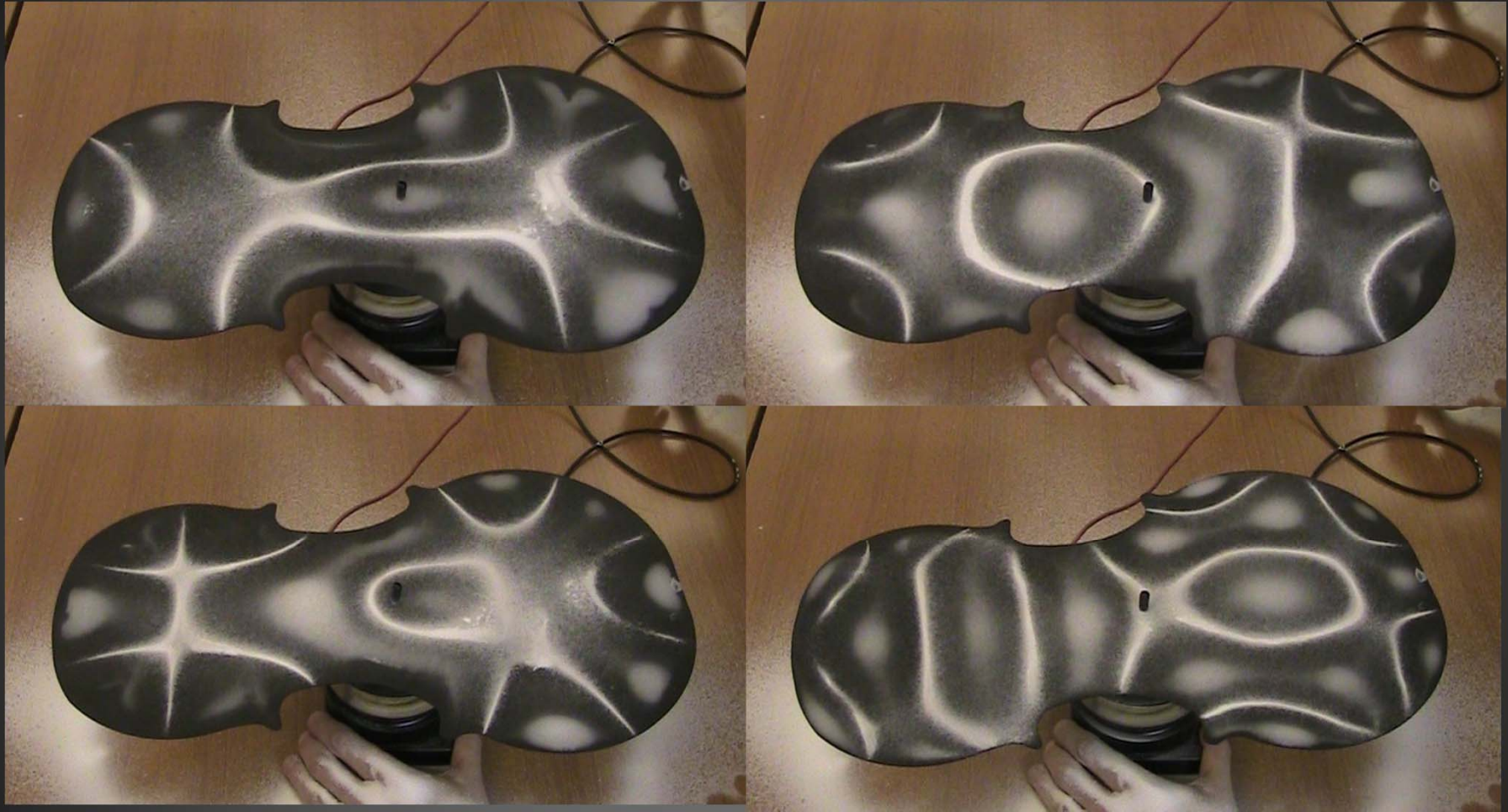
Second mode



# NORMAL MODES IN TWO DIMENSIONS (Chladni plates)



2012 October 15



2012 October 15

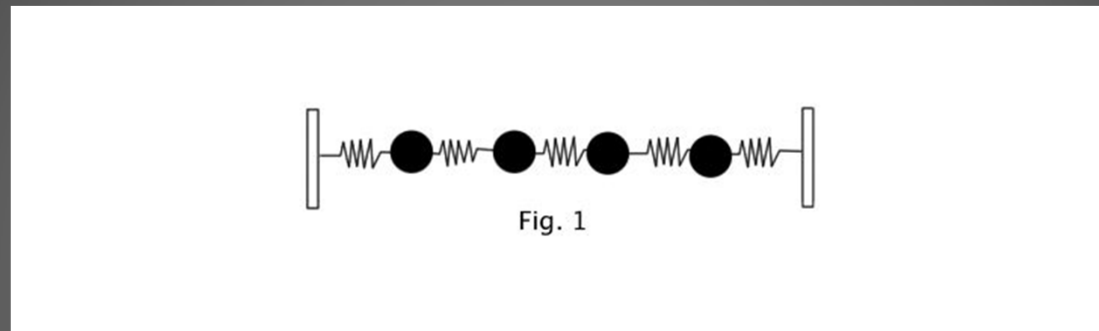
# THE RESULTS OF OUR APPROACH TO NORMAL MODES

To test our approach:

- we proposed a written questionnaire to the two groups of students
- Examined some oral interview taken during the lessons

## EXAMPLE OF QUESTION

**Q2** Consider a system consisting of five identical springs with masses as in figure

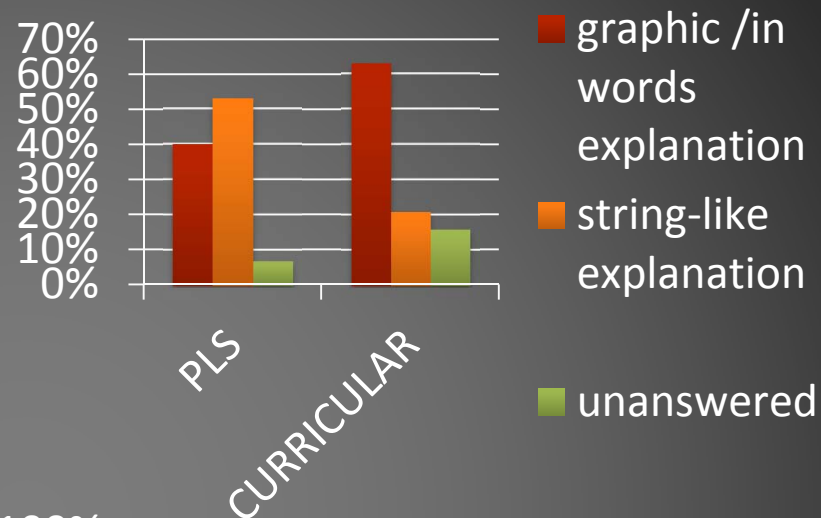


- How many normal modes does this system have? Explain your answer and describe each mode

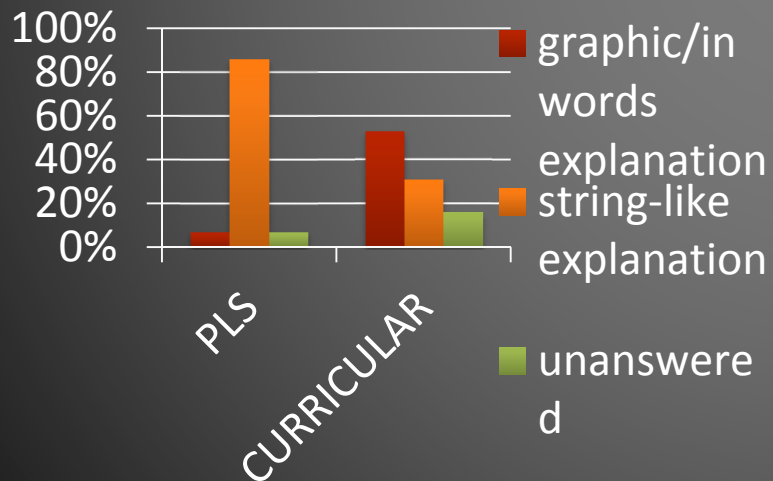
1

All students described with words and graphs correctly the first normal mode

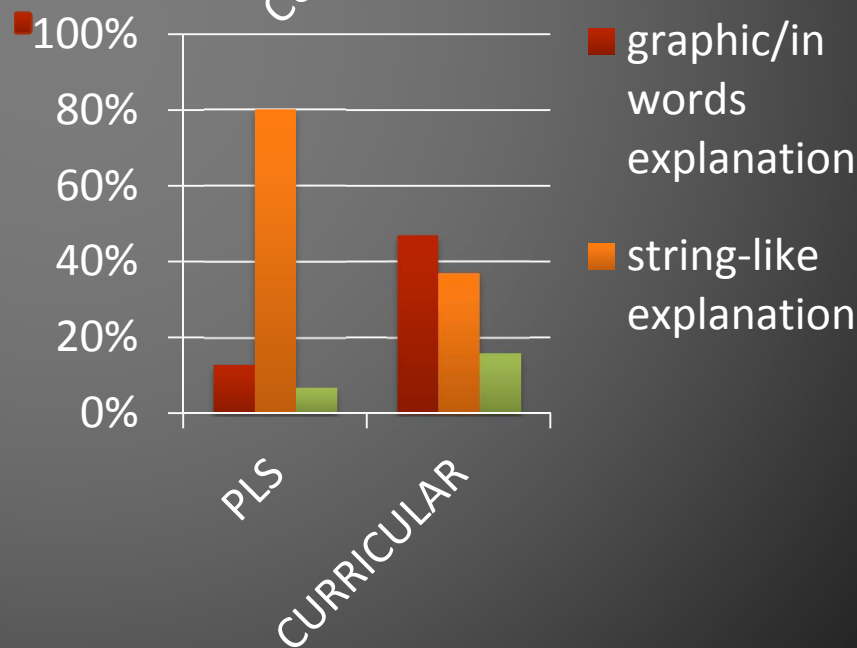
2



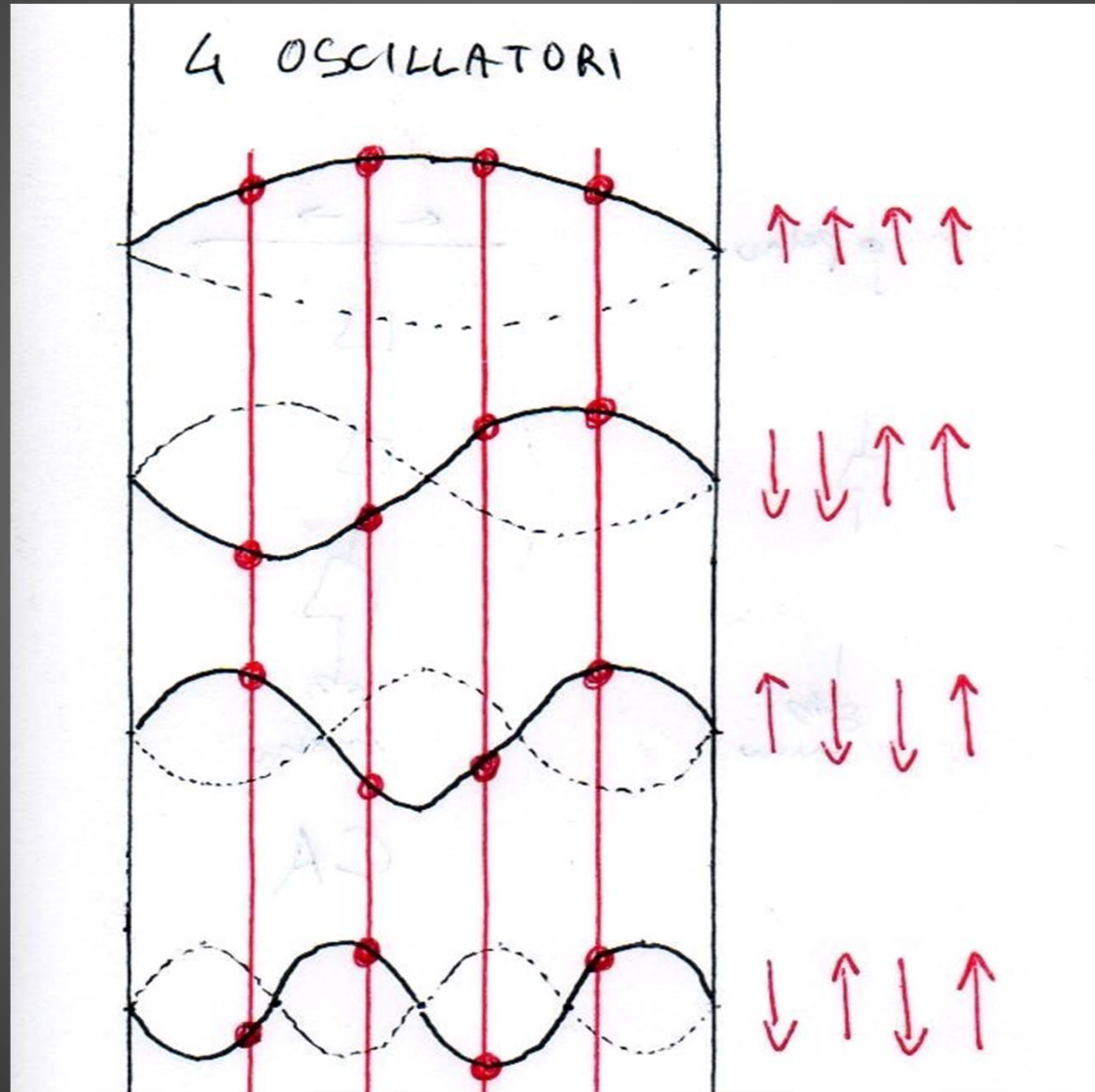
3



4



# THE STRING-LIKE GRAPHIC METHOD



2012 October 15

# CONCLUSIONS

- Normal modes are commonly not present in Italian high school curricula. Nonetheless they are a crucial point in the paths we are studying in Milano.
- The overall result is great enthusiasm of the students involved

# CONCLUSION

- Some conceptual knots are evident:
  - The difference between the oscillation of the system and the oscillation of each point in a normal mode
  - The conceptual change between normal modes in a string and stationary waves
- The use of data logging techniques and the use of video and slow motion is worthwhile for reasoning on normal modes



# Future perspectives

- Two wider experimentation on oscillations and waves for secondary school will start in a few weeks: one involving two 3rd year classes and one involving a 4th year class.
- The study of parametric behaviour of mass-spring system will be implemented
- An educational path on oscillations will be experimented with PED students

# First year produced work

- Attendance at the **W**orld **C**onference on **P**hysics **E**ducation 2012, Istanbul 1-6 july 2012 with a talk named: “A high school teaching/learning sequence on normal modes”
- Presentation at SIF 2012, Napoli 17-21 september 2012 of the report: “una proposta per l’insegnamento dei modi normali nella scuola superiore”
- The paper : “An undergraduate study of harmonic and parametric motion of a simple mass-spring system from motion waveforms” submitted to the American Journal of Physics and under referees evaluation

THANK YOU FOR THE ATTENTION

2012 October 15