Scifi-sound

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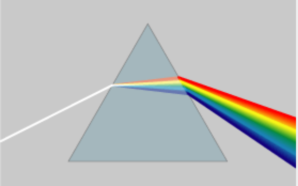
Task

Tapping a helical spring can make a sound like a "laser shot" in a science-fiction movie. Investigate and explain this phenomenon.

Basic explanation

Dispersion

- Phase velocity of a wave as a function of frequency
- Frequencies propagate at different velocities through the medium
- Only in certain materials (solids and liquids)
- Applies to optical as well as acoustic waves
- More dense materials are usually more dispersive

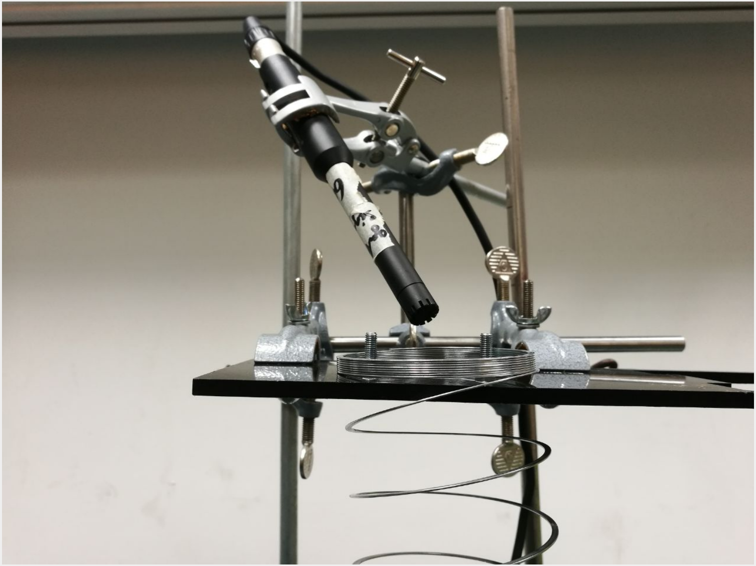


Slinky

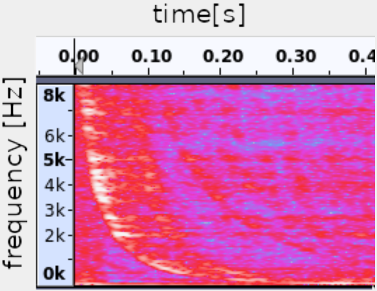
- Helical spring often made of metal
- Highly dispersive
- Tapping it produces a short signal consisting of multiple frequencies
- Wave dissects into its component frequencies
- Higher frequencies are heard before the lower ones, thus producing the "scifi-sound"

Experimental setup

Experimental setup



Experimental results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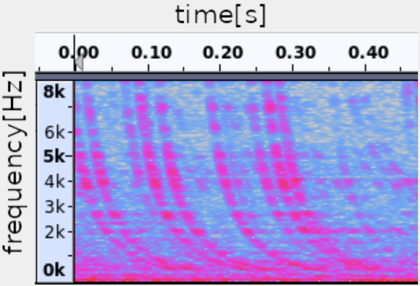
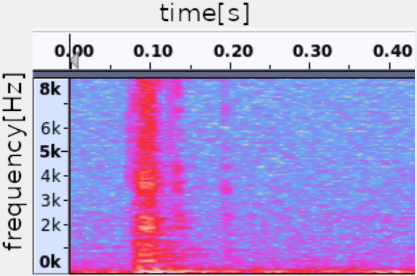
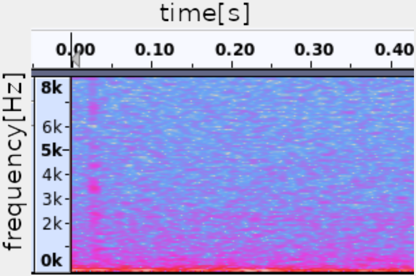
0.00
0.10
0.20
0.30
0.4
frequency [Hz]
8k
6k
5k
4k
3k
2k
0k


time[s]
0.00
0.10
0.20
0.30
0.40
frequency[Hz]
8k
6k
5k
4k
3k
2k
0k

Response curve plastic





Theory

Formulas

Euler-Bernoulli ideal bar equation[1]:

$$\frac{\partial^2 u}{\partial t^2} = -\kappa^2 \cdot \frac{\partial^4 u}{\partial x^4} \tag{1}$$

$$t_D = \frac{1}{2\sqrt{\pi \kappa f}} \tag{2}$$

$$f(t) = \frac{1}{8\pi\kappa t^2} \tag{3}$$

where:
f = frequency [Hz]
t = time [s]
t_D = duration time [s]
κ = fit parameter

[1] Parker, Julian, et al. 'Modeling methods for the highly dispersive slinky spring: a novel musical toy.' Proceedings of the 13th International Conference on Digital Audio Effects 2010.

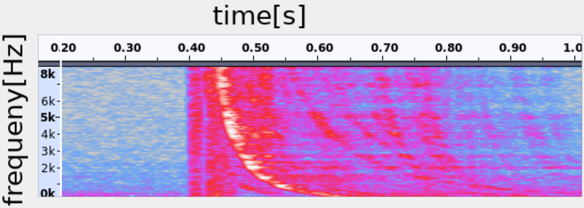
Fit parameter κ

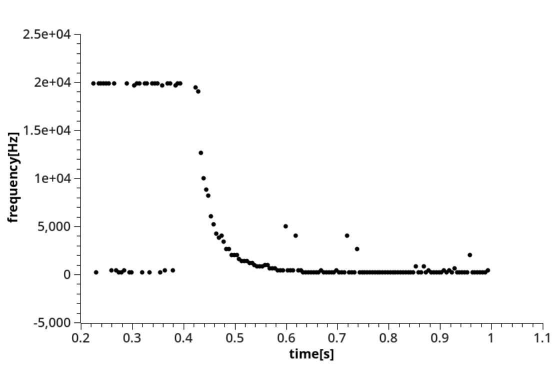
κ determines how widely spread the frequencies are.
It is dependent on material properties, such as:

- Density
- E-Modulus
- Length

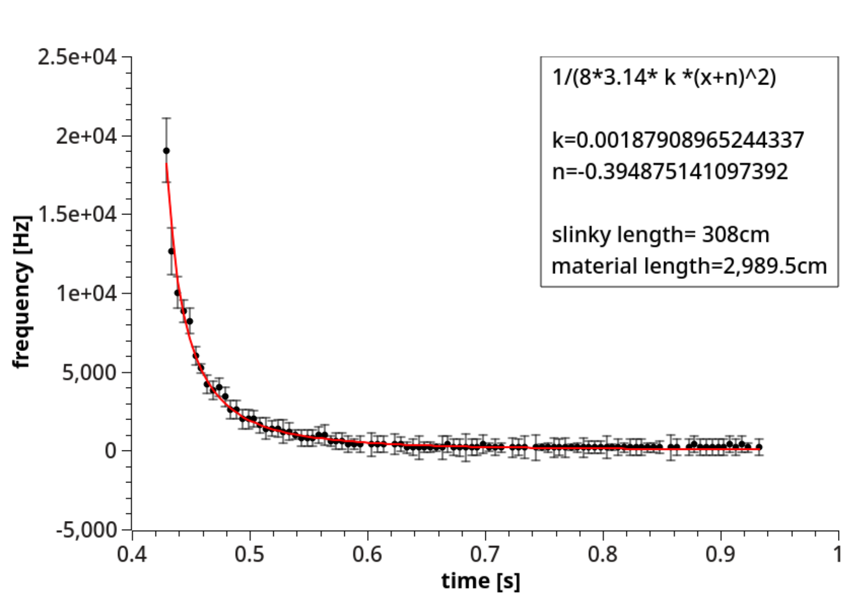
Theory-Experiment Comparison

Data processing

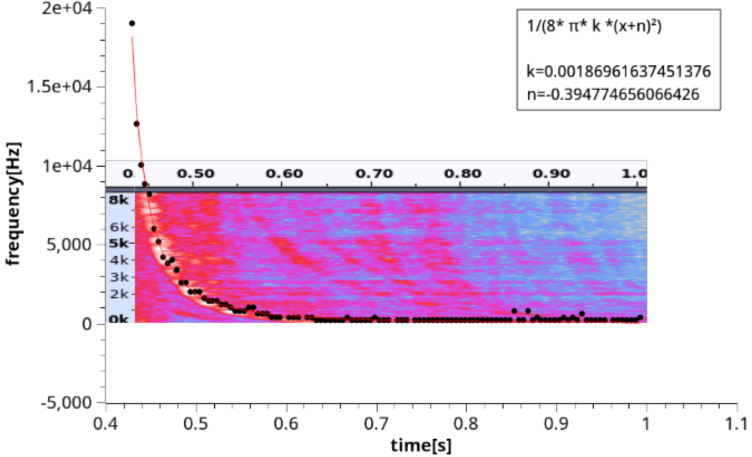




Fitted function



Direct comparison



Outlook