17. STANDING WAVES

Team Croatia

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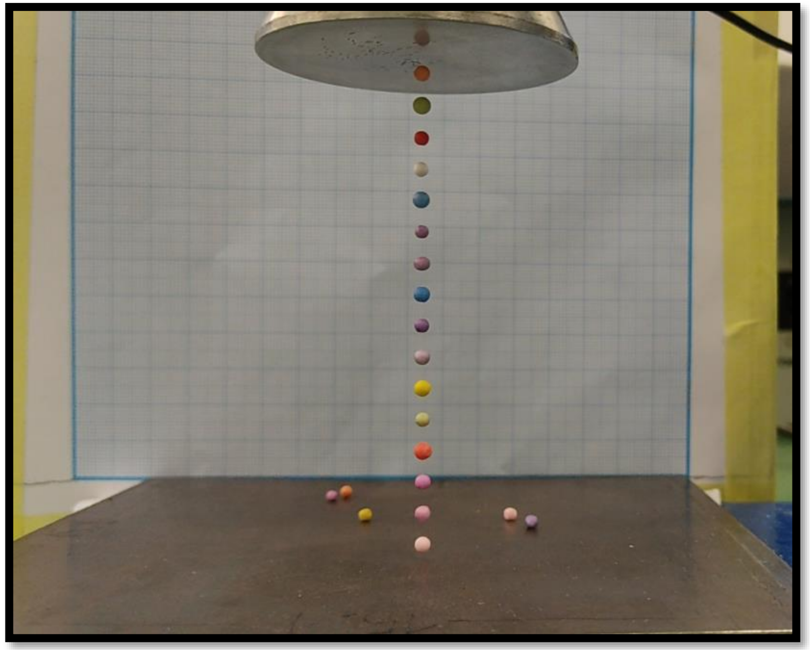
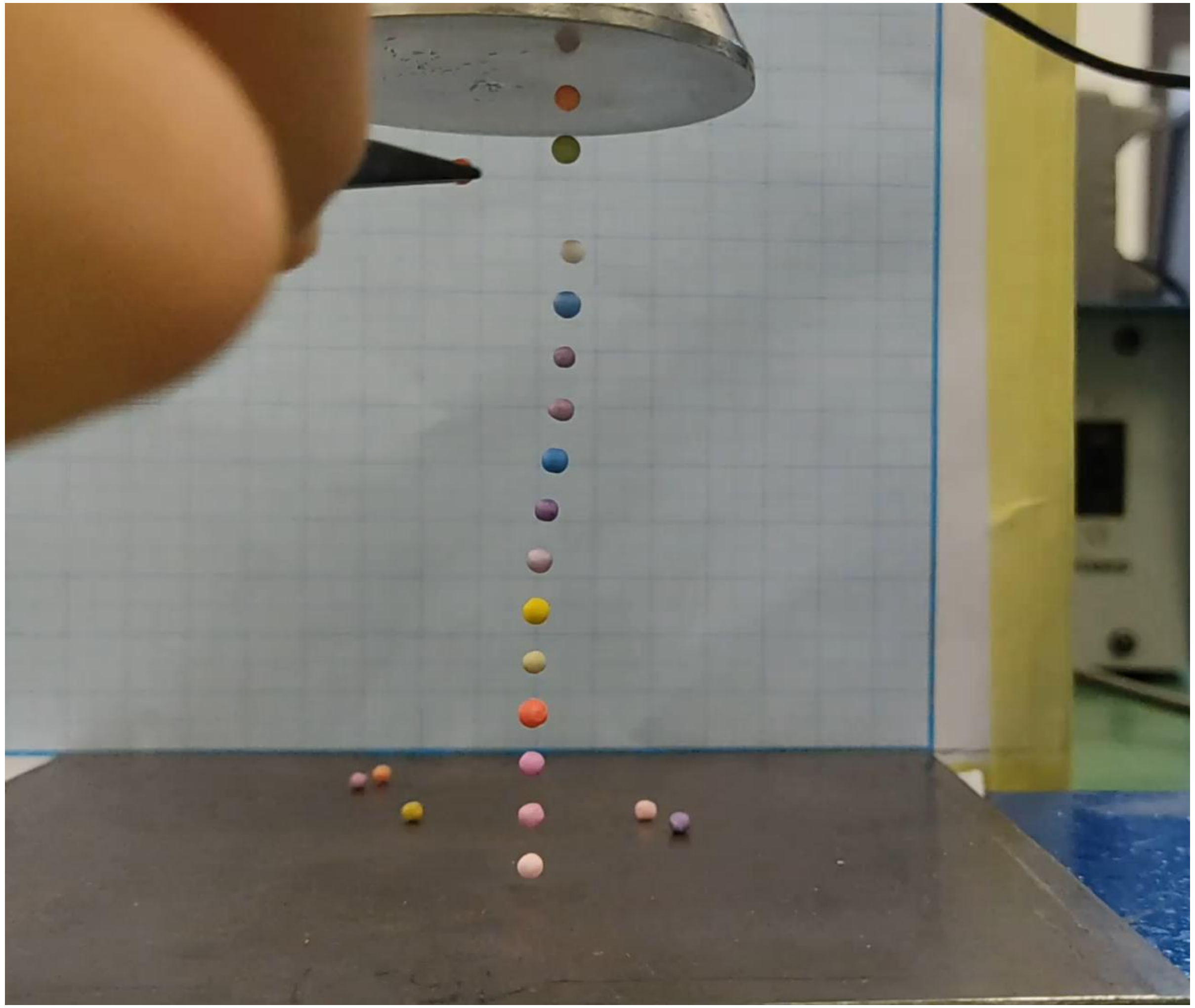
PROBLEM STATEMENT

„With right frequency played from emitter, small balls can be levitated by standing waves between speaker and a reflector. Investigate the phenomenon and parameters of the system.”



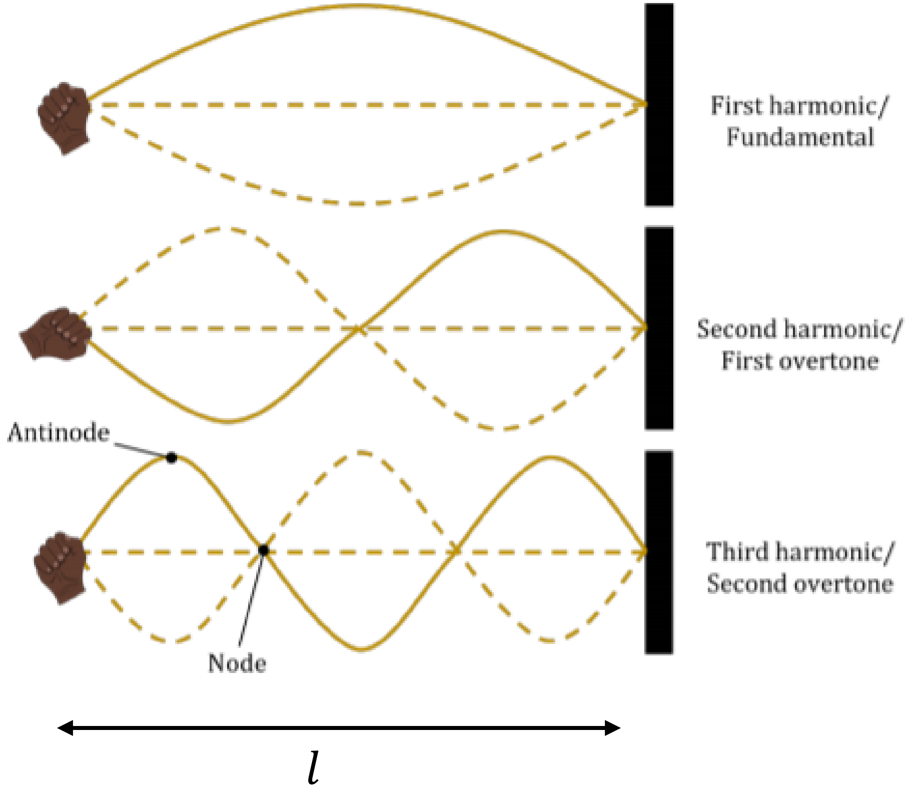
DEMONSTRATION



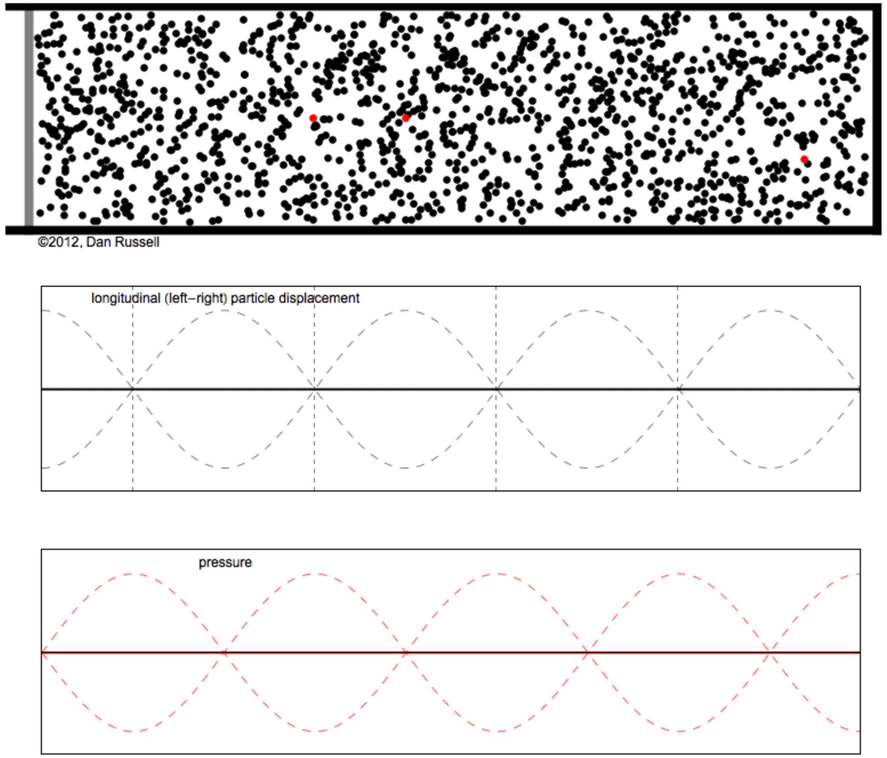
STANDING WAVES

- Nodes and antinodes
- $\lambda = \frac{v}{f}$
- $l = \frac{\lambda n}{2}$

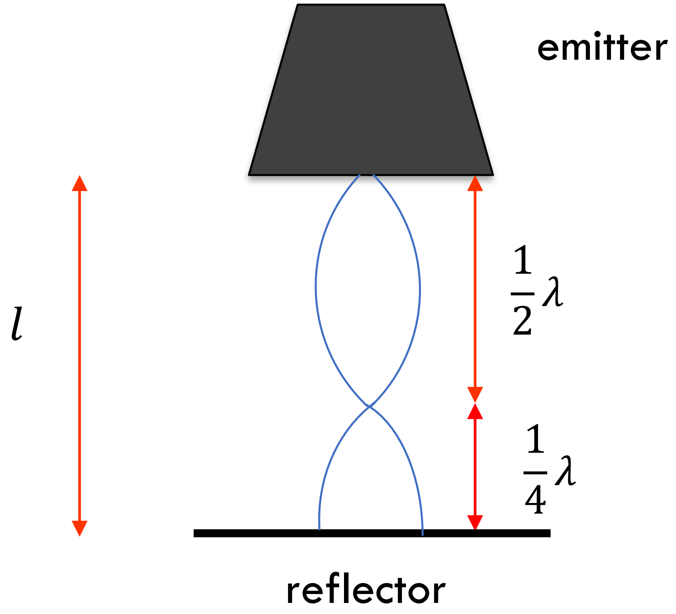
number of harmonic



ACOUSTIC LEVITATION



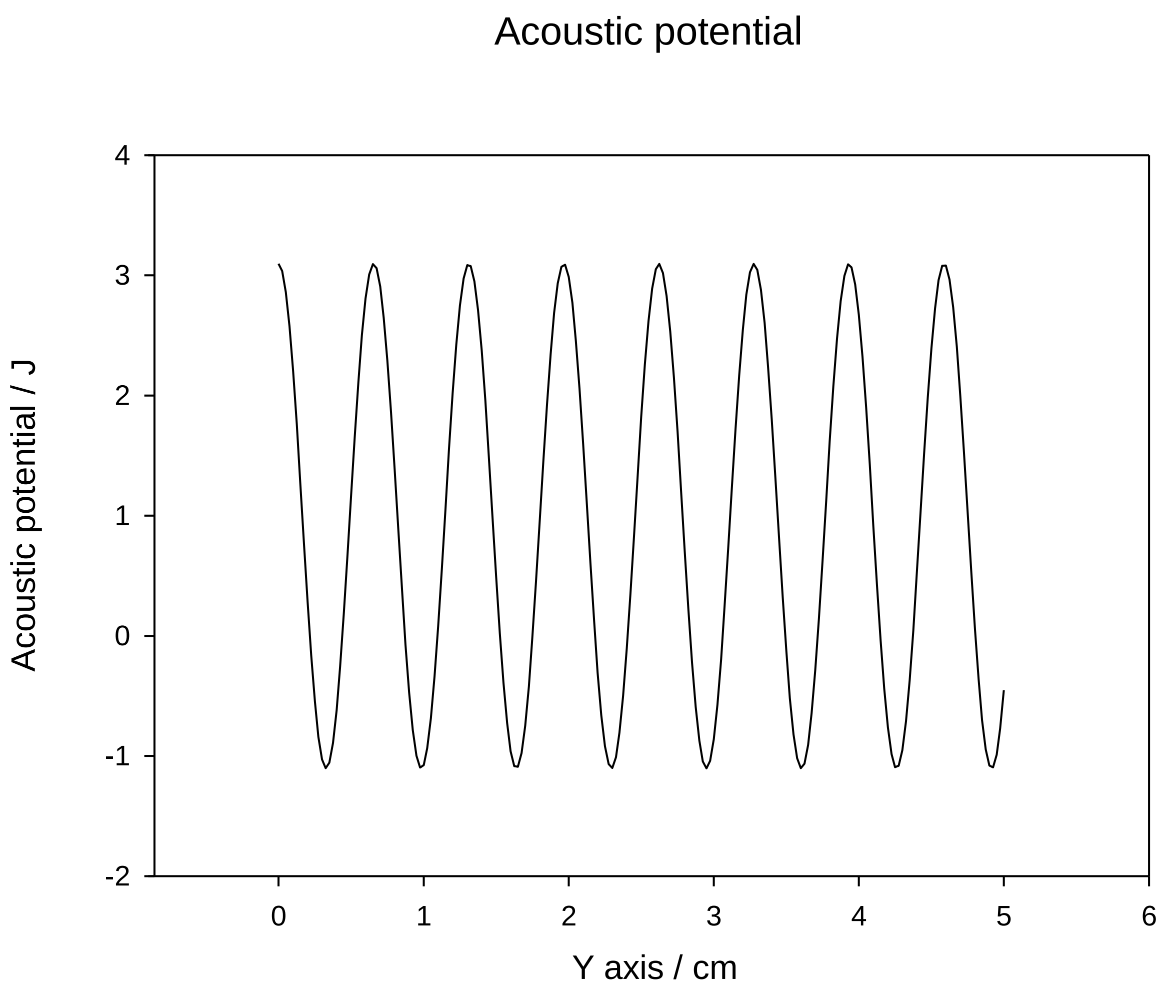
- Levitation points – low pressure



$$l = \frac{n}{2}\lambda + \frac{1}{4}\lambda = \lambda\left(\frac{2n+1}{4}\right)$$

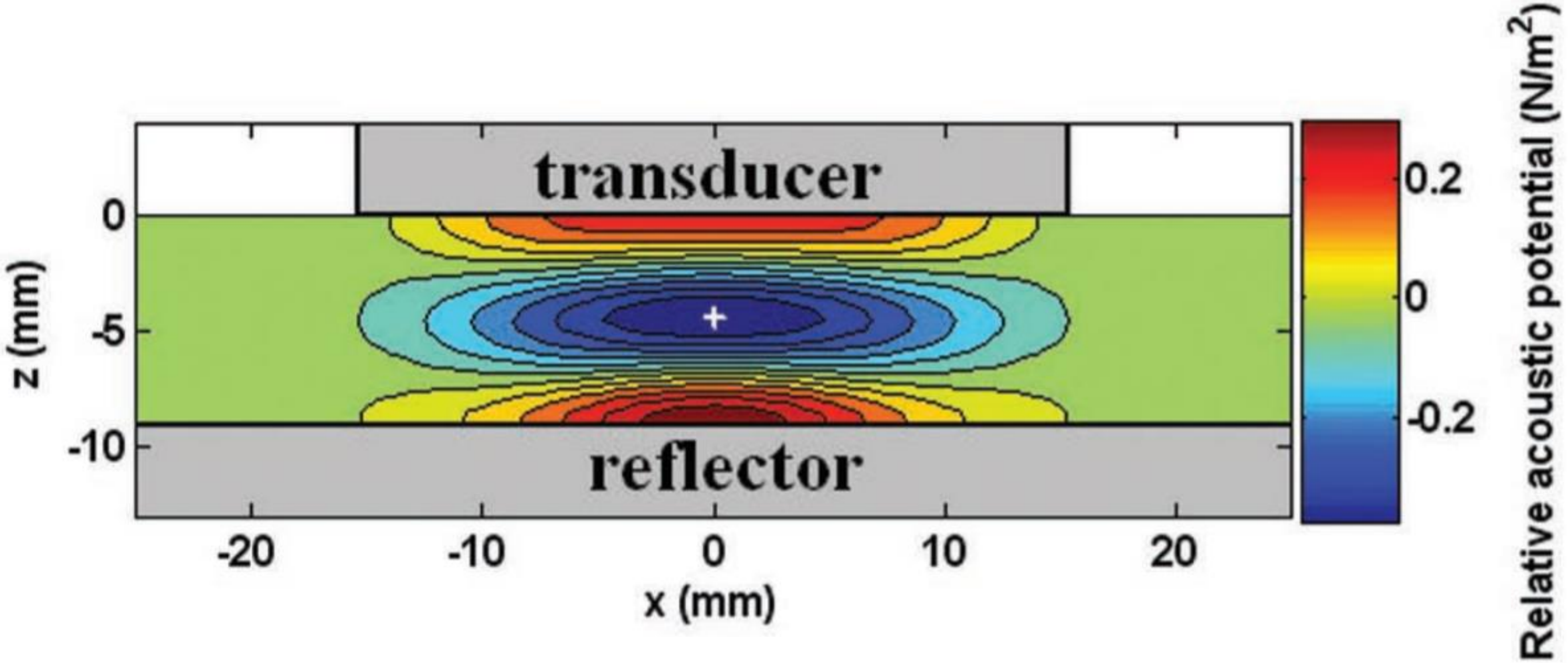
Gorkov potential

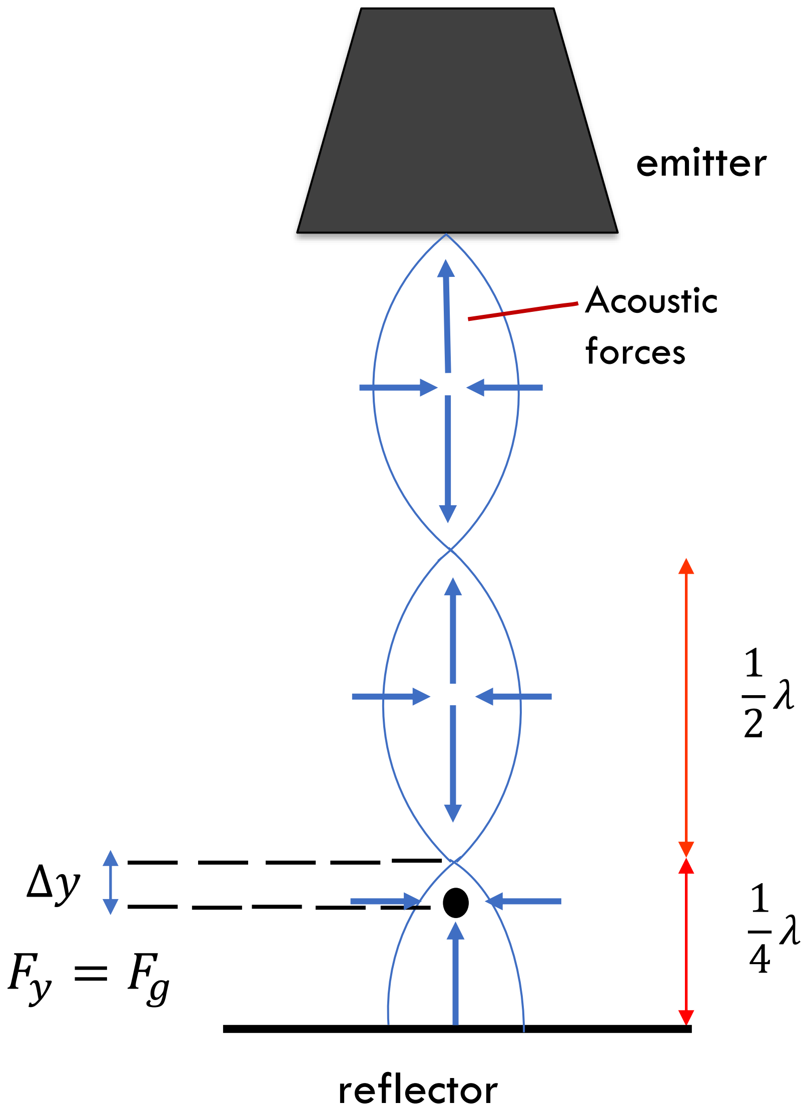
- $U = 2\pi R^3 \left(\frac{\langle p^2 \rangle}{3\rho_0 c^2} - \frac{\rho_0 \langle u^2 \rangle}{2}\right)$
- $\langle u^2 \rangle = \frac{P_{eff}}{A c \rho_0} sin^2\left(\frac{\pi f y}{c}\right)$
- $\langle p^2 \rangle = \frac{4 c \rho_0 P_{eff}}{A} cos^2\left(\frac{\pi f y}{c}\right)$



Gorkov potential

- $F = -\nabla U$
- $k_x = \frac{\partial^2 U}{\partial x^2}$





- Damped harmonic oscillation around nodes
- Across one amplitude
- $\frac{mv^2}{2} = \frac{kx^2}{2}$
- $k = m\frac{v^2}{x^2}$

Hypotheses

H1: Stable levitation will occur at $\lambda(\frac{2n+1}{4})$ from reflector, and $\frac{n}{2}\lambda$ from emitter

H2: If balls are disturbed, damped oscillation is going to occur around levitation points

H3: Elastic constant will get bigger while aproaching x=0

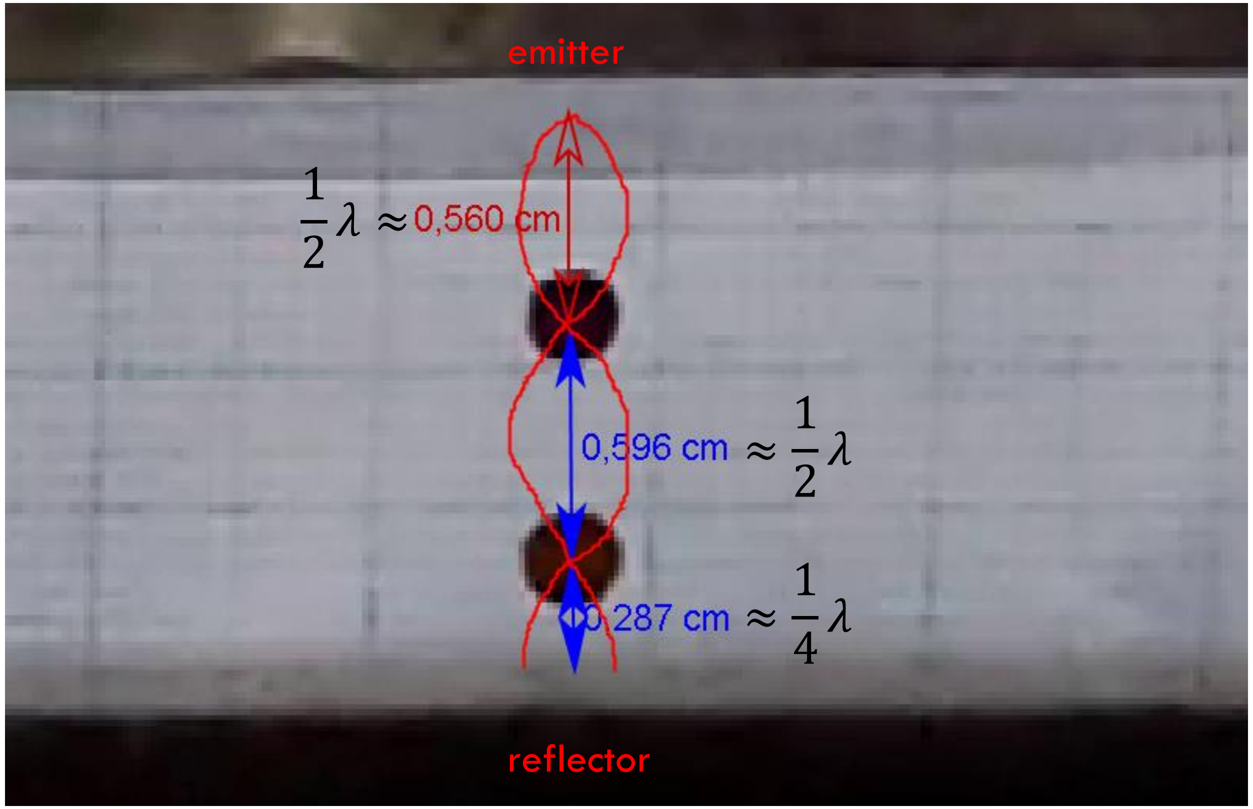
EXPERIMENT SETUP

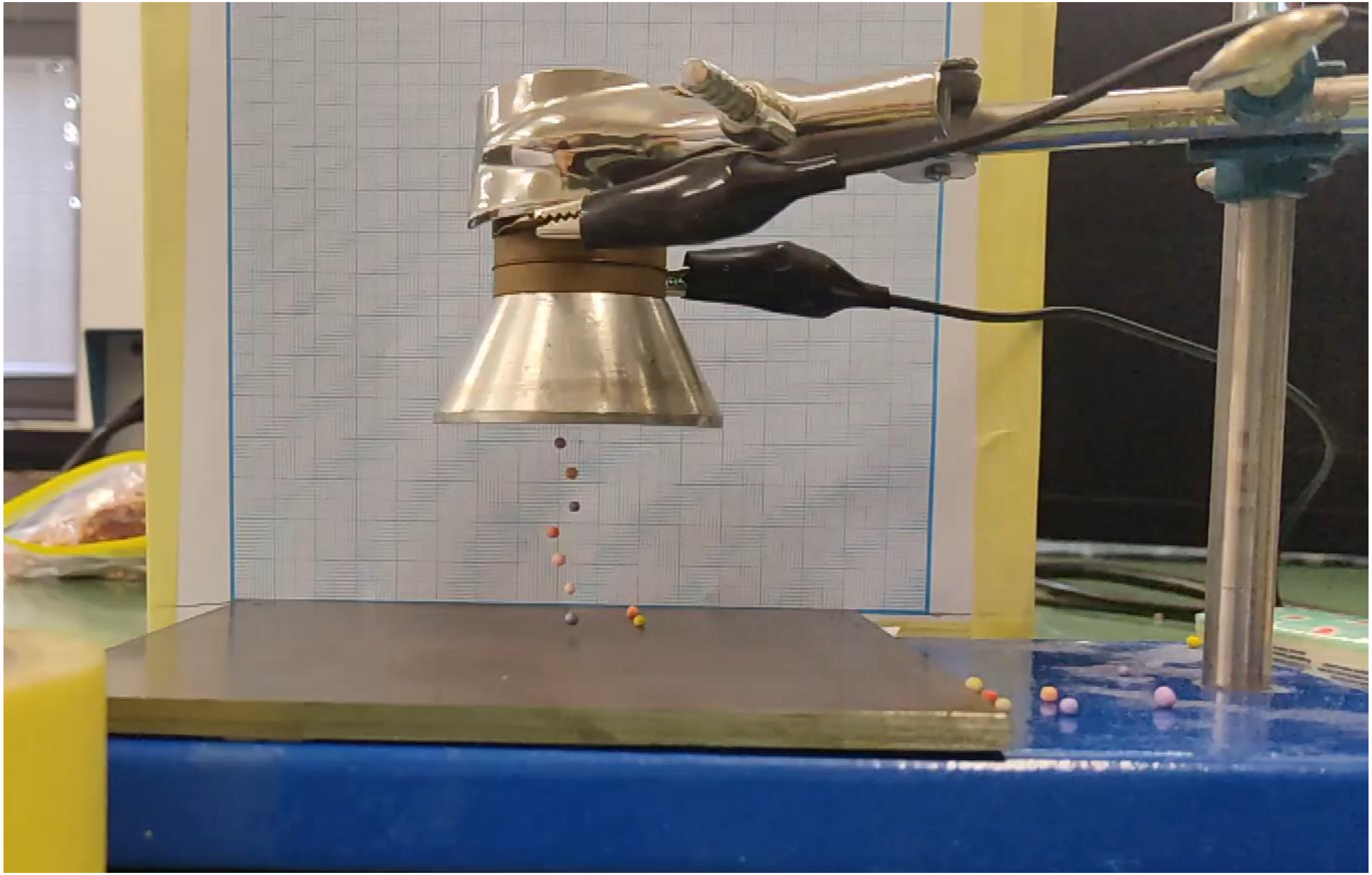
- Ultrasonic transducer, $f_r \approx 30000\ Hz$
- Function generator
- Power amplifier
- Oscilloscope
- X-y and z-y positions
- Recorded and tracked oscillations

H1: Stable levitation will occur at $\lambda(\frac{2n+1}{4})$ from reflector, and $\frac{n}{2}\lambda$ from emitter ✓

$$\lambda = \frac{c}{f} = 0.01143\, m = 1.143\, cm$$

- Deviation from calculated distance causes instability

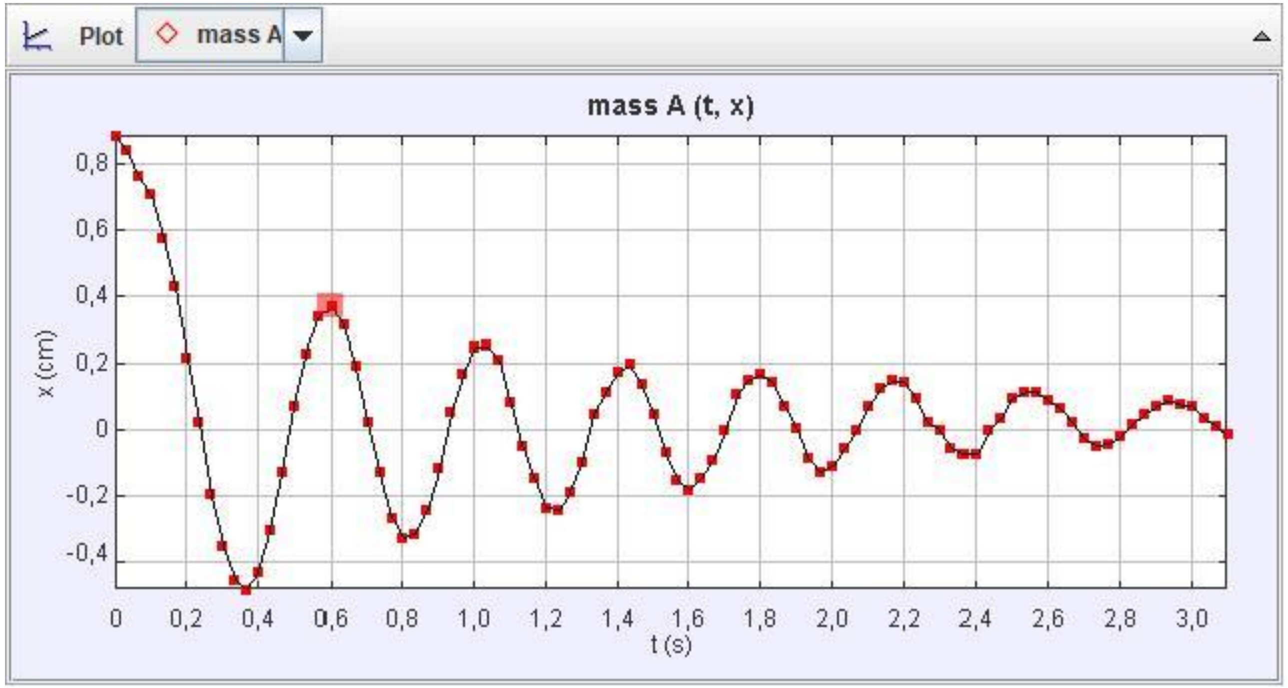




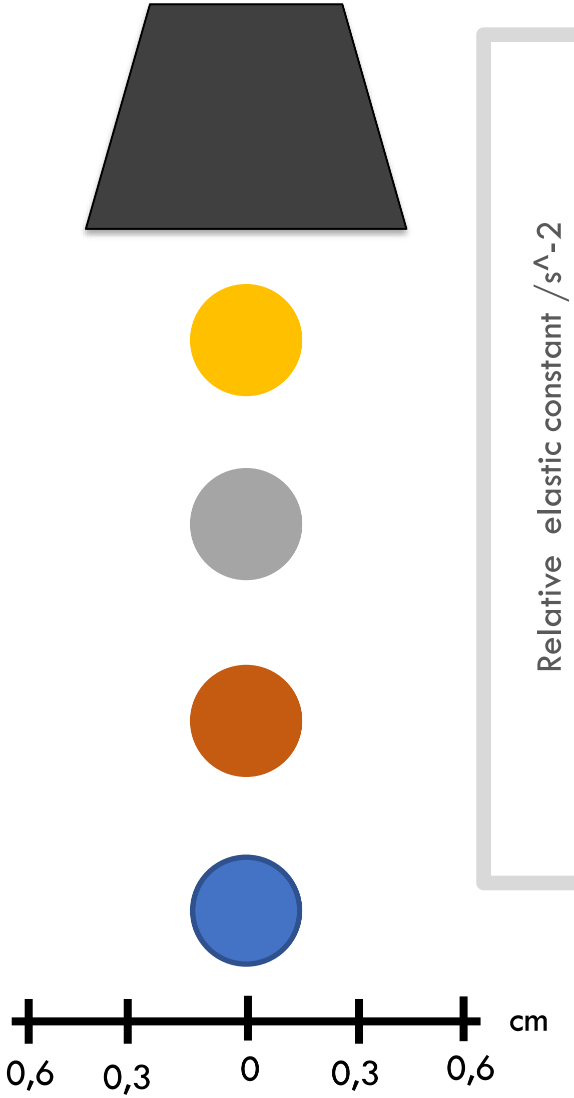
H2: Damped oscillations occurs ✓

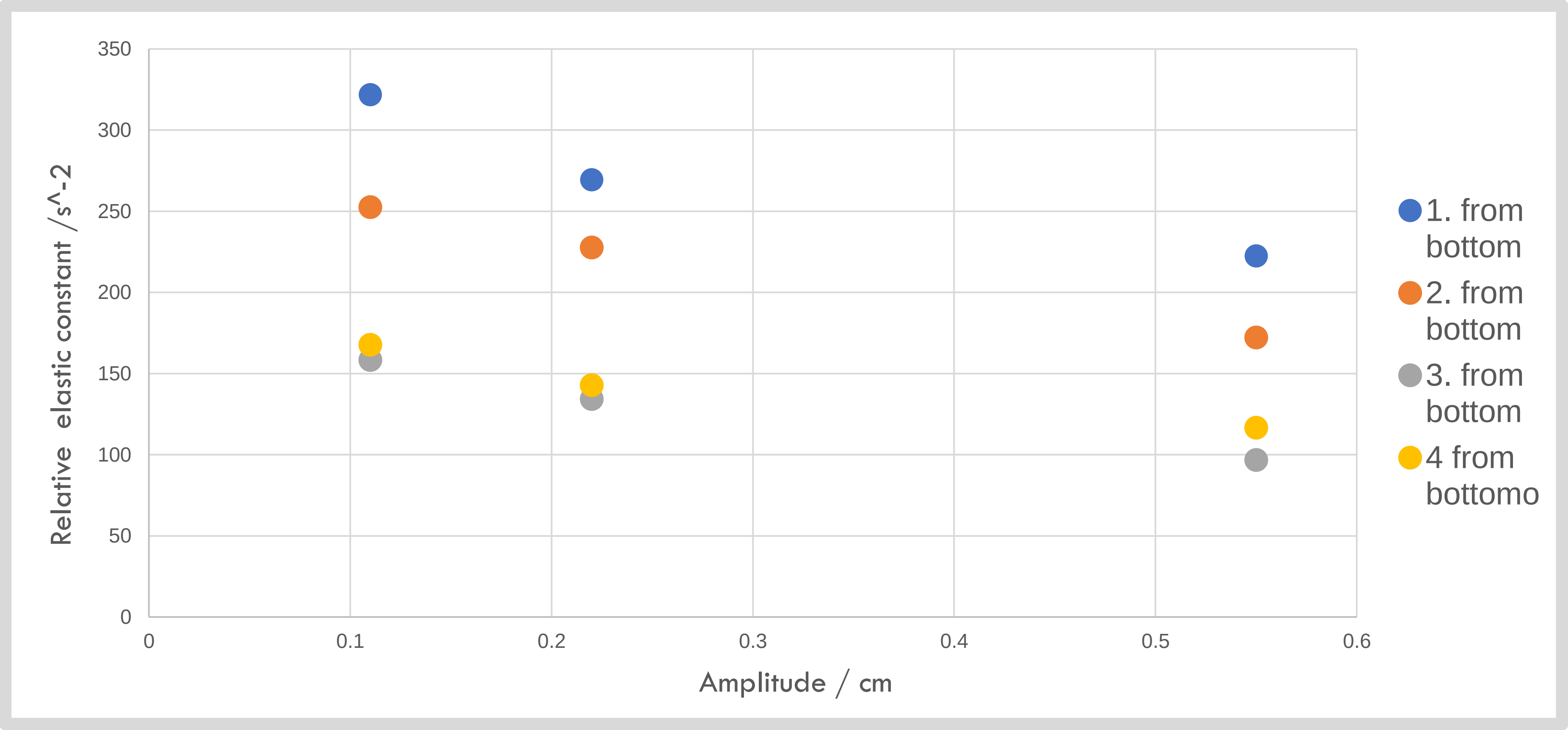
- Relative elastic constant

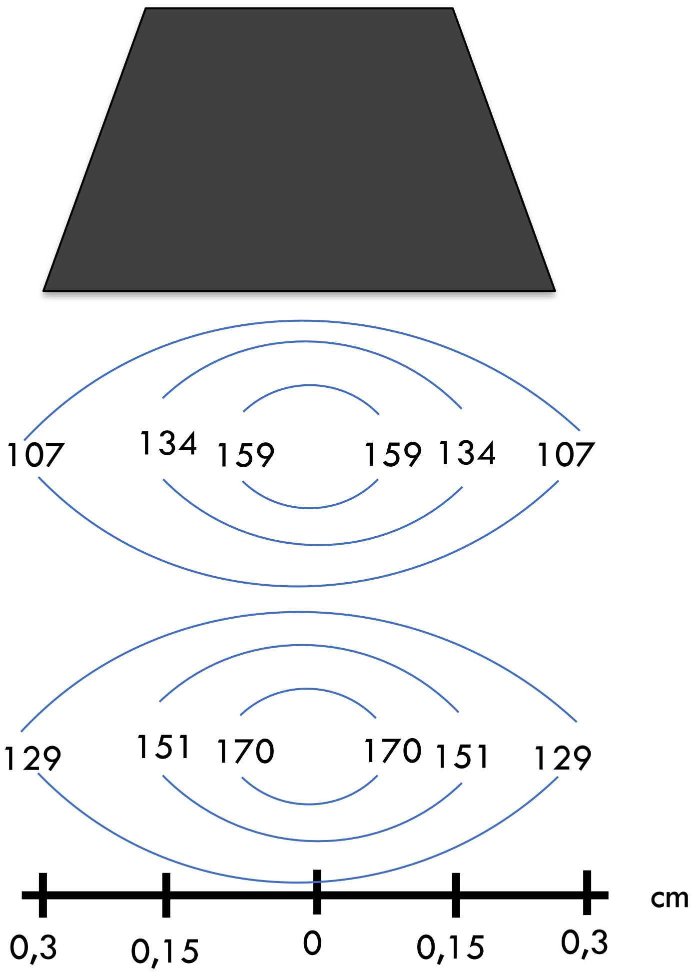
$$\tilde{k} = \frac{k}{m} = \frac{mv^2}{mx^2} = \frac{v^2}{x^2}$$

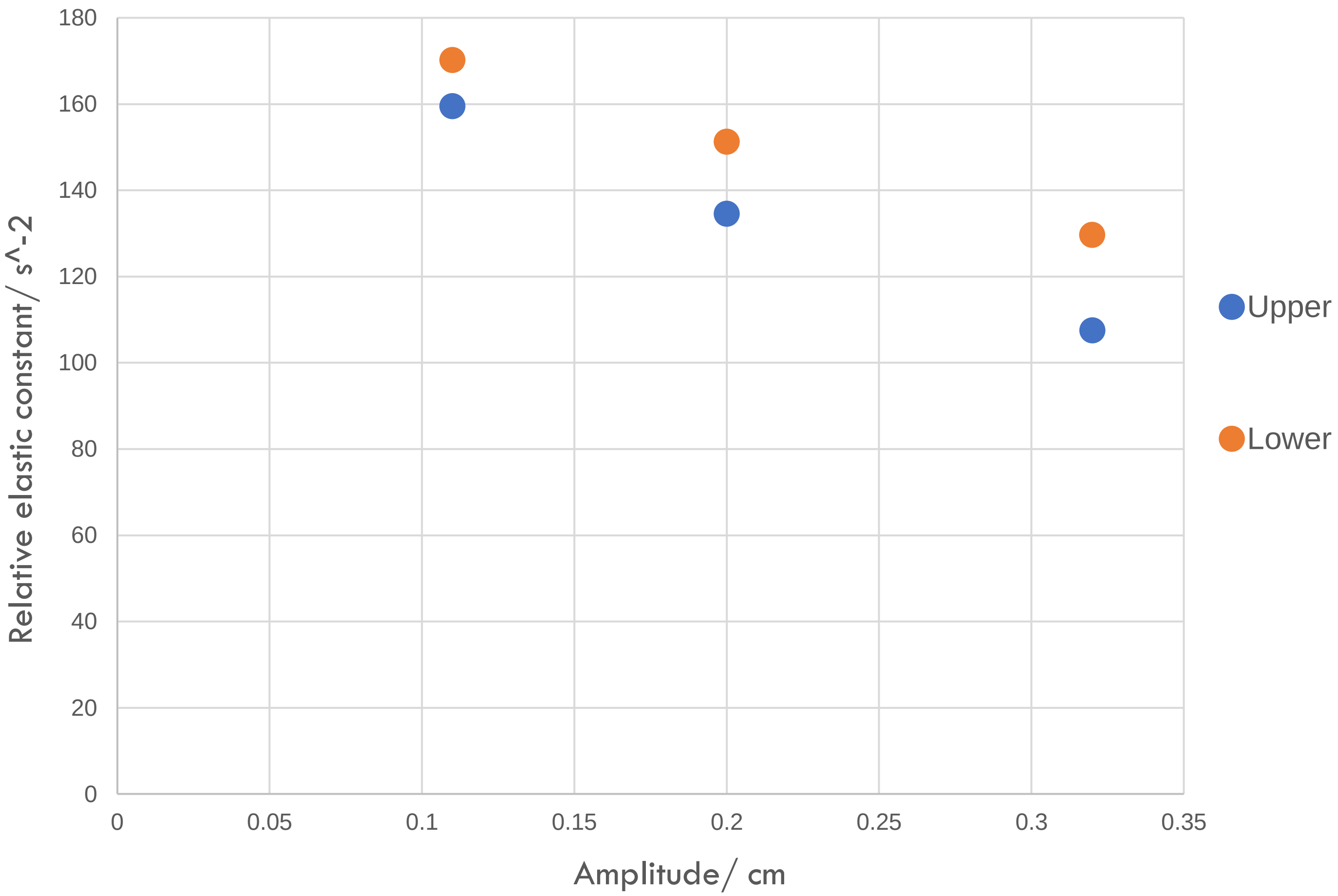


H3: Elastic constant will get bigger while aproaching x=0






107
134
159
159
134
107
129
151
170
170
151
129
cm
0,3
0,15
0
0,15
0,3

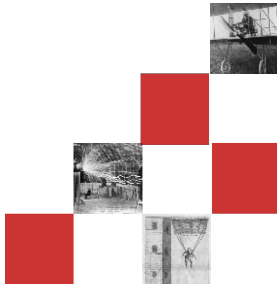

180
160
140
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Relative elastic constant/ s^-2
Amplitude/ cm
Upper
Lower

Conclusion

H1: Stable levitation will occur at $\lambda(\frac{2n+1}{4})$ from reflector, and $\frac{n}{2}\lambda$ from emitter

H2: If balls are disturbed, damped oscillation is going to occur around levitation points

H3: Elastic constant will get bigger while aproaching x=0



Literature

1. https://ieeexplore.ieee.org/document/5417206
2. https://aip.scitation.org/doi/10.1063/1.3652976
3. https://www.researchgate.net/publication/322143783_Review_of_Progress_in_Acoustic_Levitation
4. http://dx.doi.org/10.1063/1.1391398
5. Stability of a Particle Levitated in an Acoustic Field; Luke Wortshman