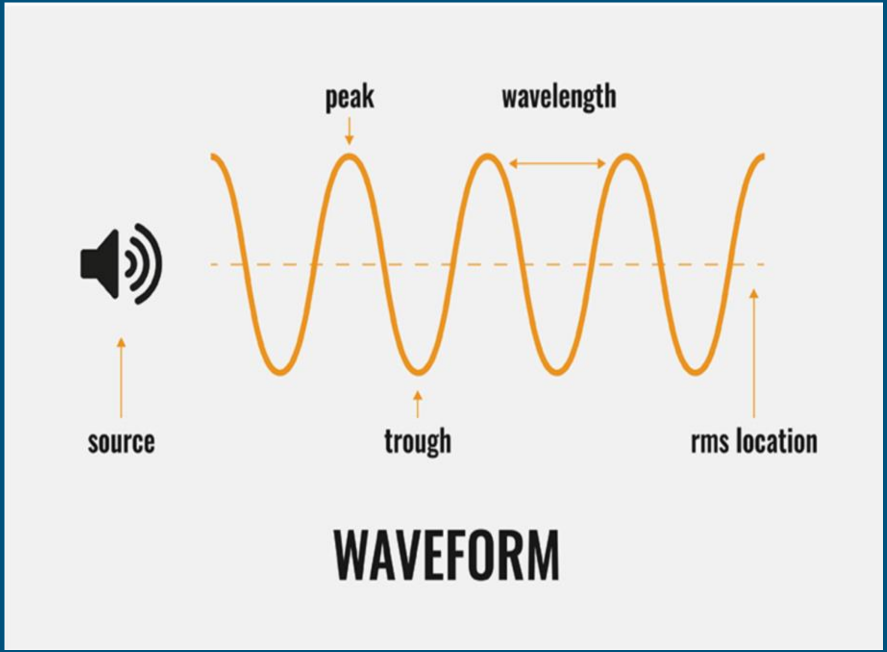
Acoustic Levitation

By TJJ: John Peterson, Tyler Owens, and Juliana Ortiz-Castillo.
May 2nd, 2023, Salt Lake City, Utah

Introduction

- Acoustic levitation
  - Fairly new
  - fairly unstudied
- But how does it work?
  - Constructive and destructive sound waves
- Potential Uses?
  - Study of sound waves
  - Study of mass transfer
  - Others?

Acoustic Waves

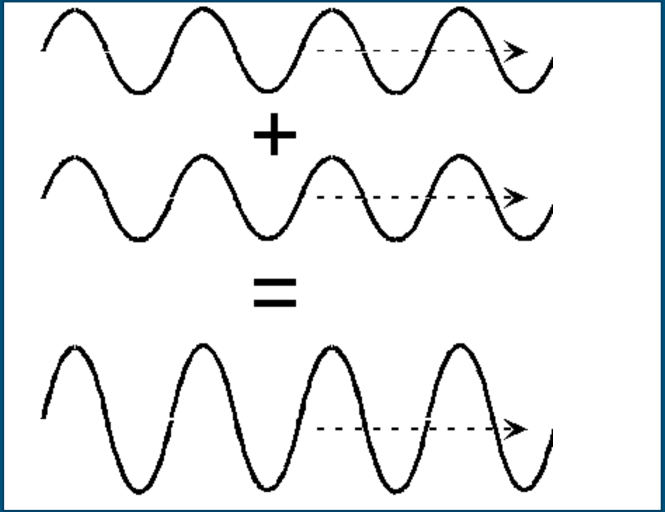


How can we describe a sound wave?

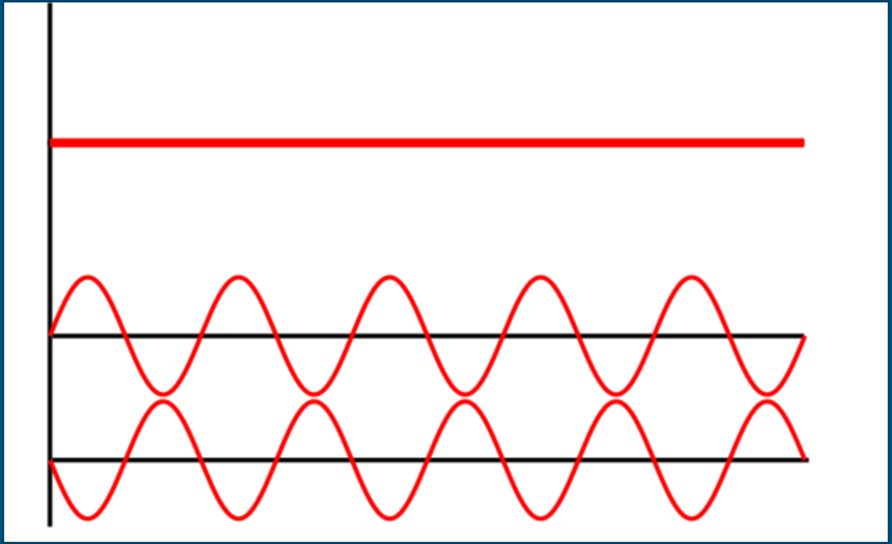
Disturbance of particles within a medium

Waves Interaction

CONSTRUCTIVE.

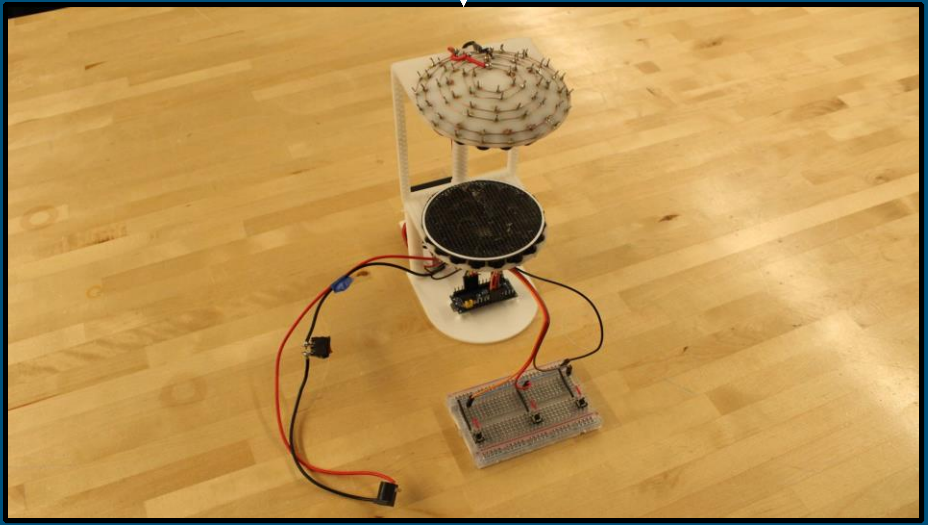


DESTRUCTIVE.



Objectives:

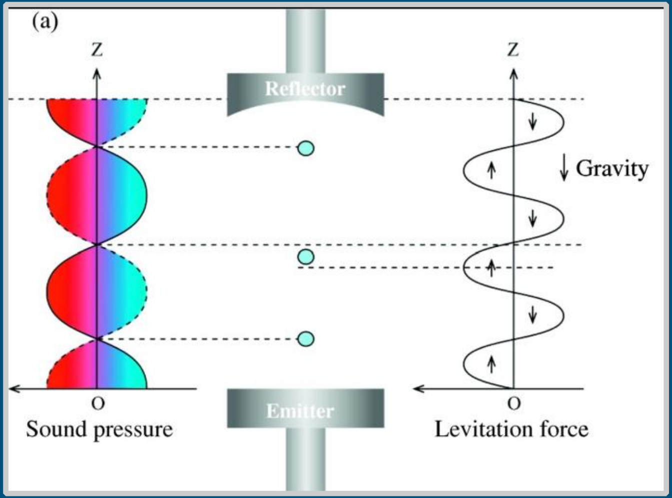
- Build an operating acoustic levitator and create a K-12 outreach module.
    - Success!
- Measure how long it takes water and other fluid substances to evaporate
    - Success (as seen later)!
- Measure the radius of time of water and other fluid substances
    - Success (as seen later)!
- Interpret the mass transfer data
    - Attempts shown later



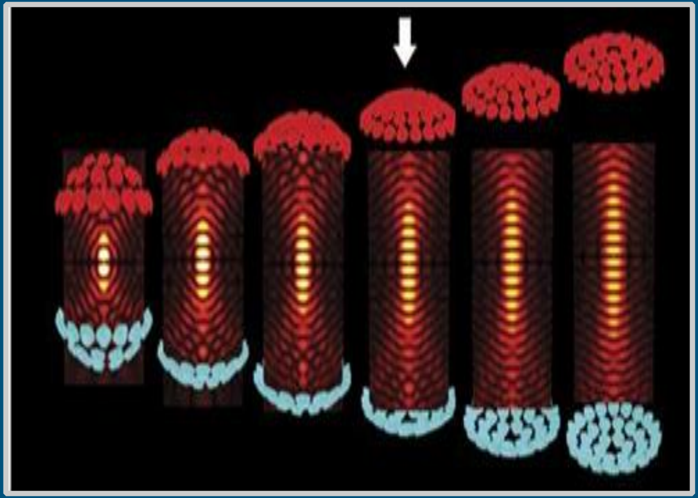
Acoustic levitator in Single Axis Arrangement

Prototypes

RESONANT

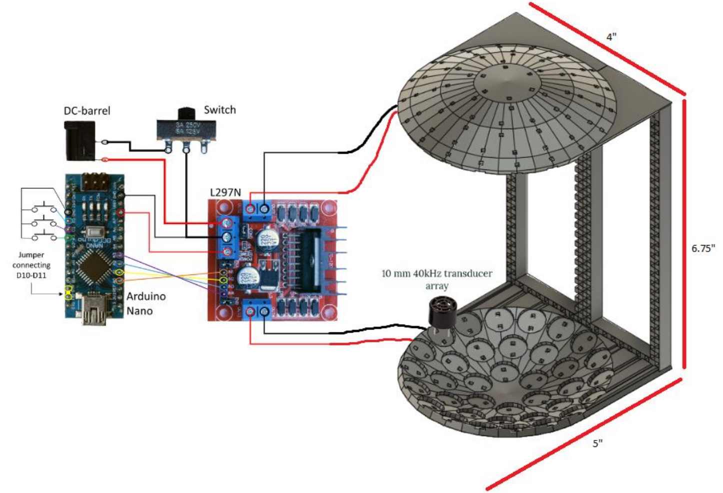


NON-RESONANT



Materials

- Acoustic levitation kit (found here)
- 3D printer and filament
- Arduino kit (found here)
- Mesh



Link to help build your own acoustic levitator

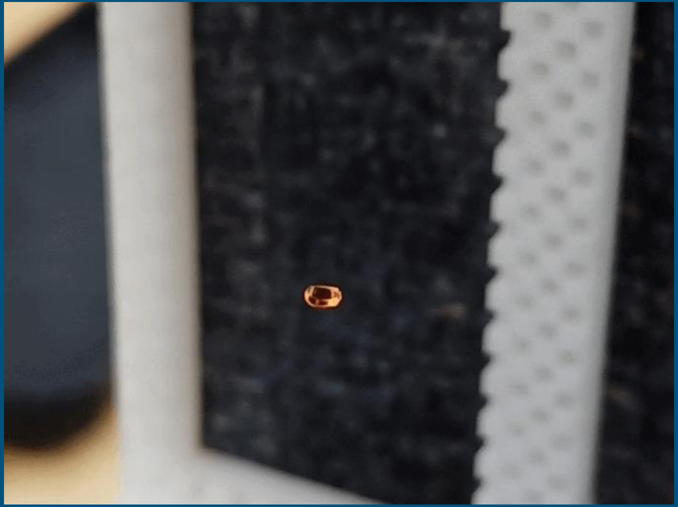
Methods

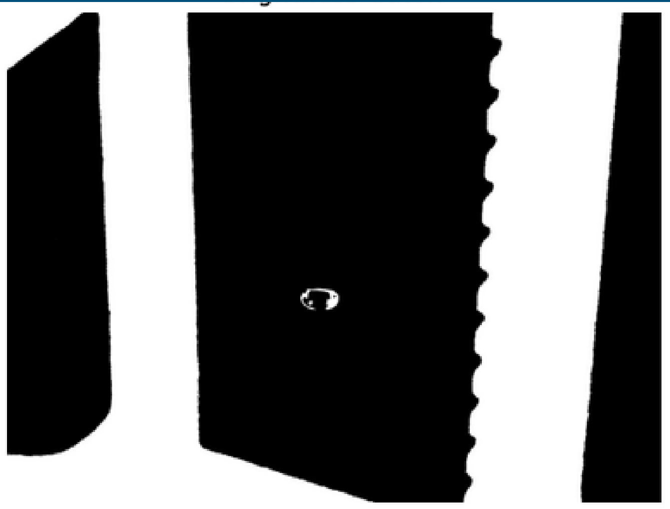
- 3D print apparatus
- Solder on transducers
- Wire circuit together
- Place fluid onto a central node (with syringe)
- Take one picture every minute to measure the radius of the liquid

Link to help create your own acoustic levitator

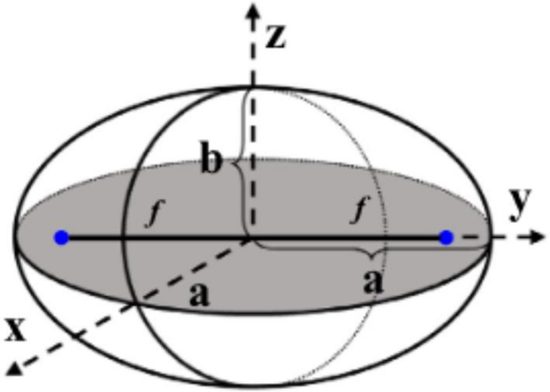
Mass Transfer

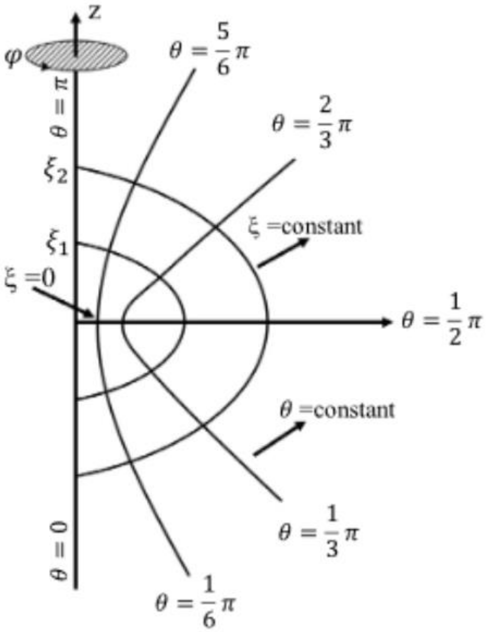
- Our machine can’t levitate dense or large objects
- Objects we levitated:
  - Styrofoam, water, methanol*, isopropanol, dry ice
- Measure the radius of the liquids over time
  - Theoretically, they should evaporate





Mass Transfer Theory

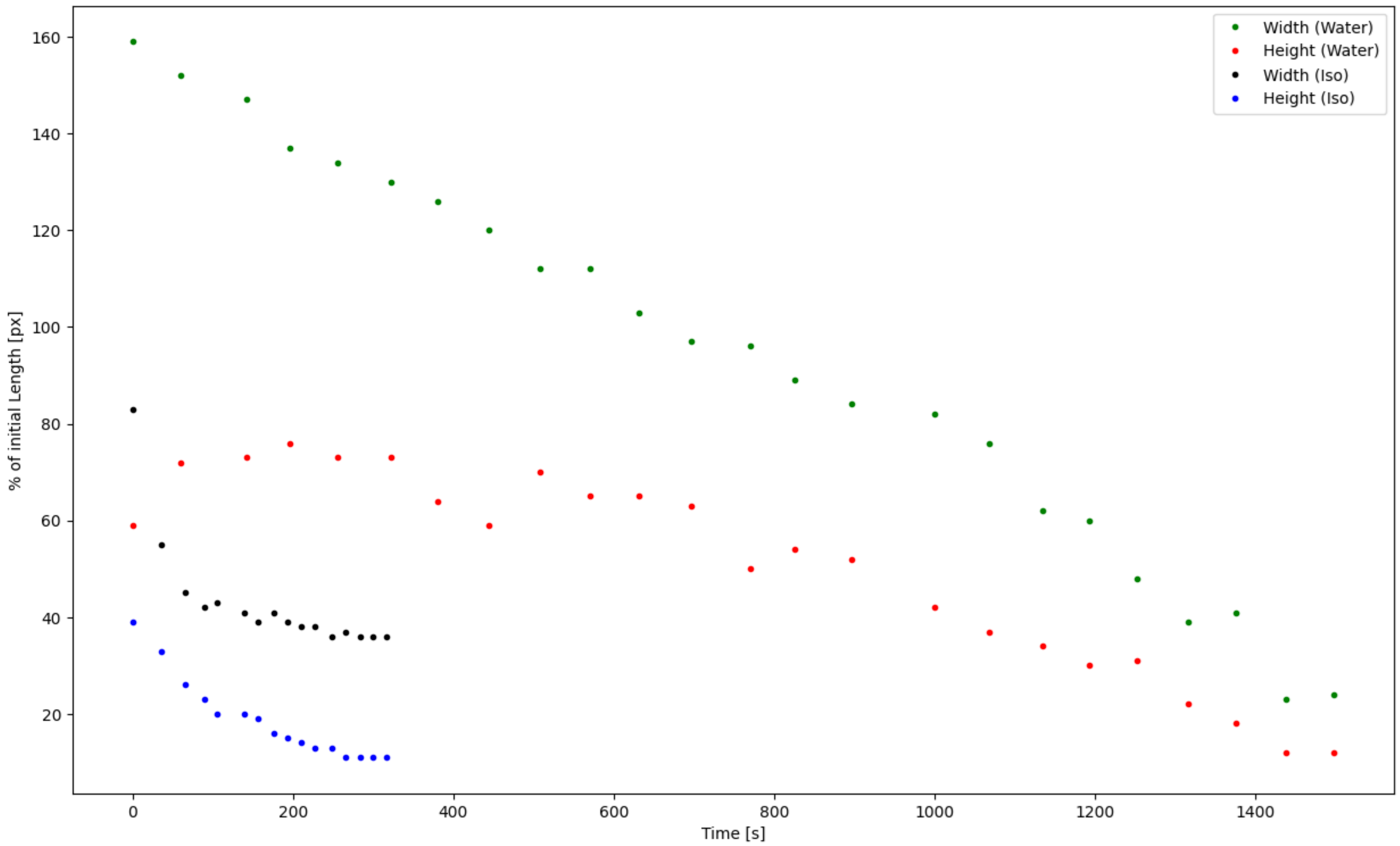




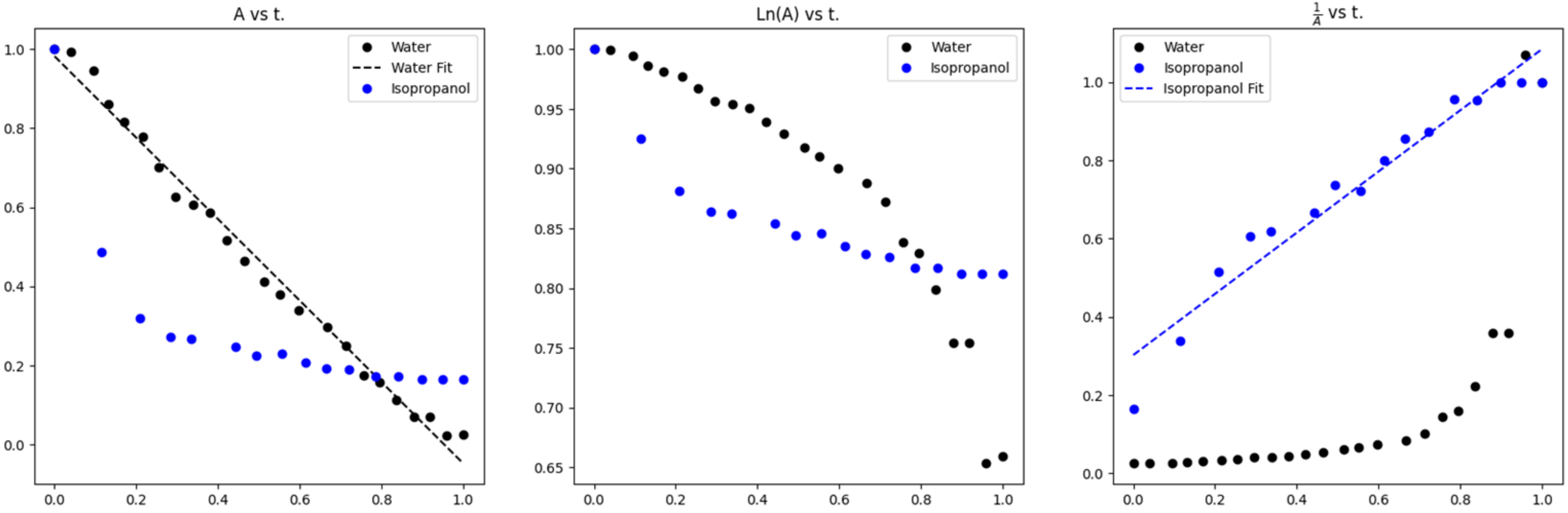
$$\dot{m}(\theta)_{eva} = \rho_g \mathfrak{D}_g \frac{A_{os}}{L_c} \cdot Sh(\theta) \cdot \frac{y_{vap,s}(\theta) - y_{vap,\infty}}{1 - y_{vap,s}(\theta)}$$

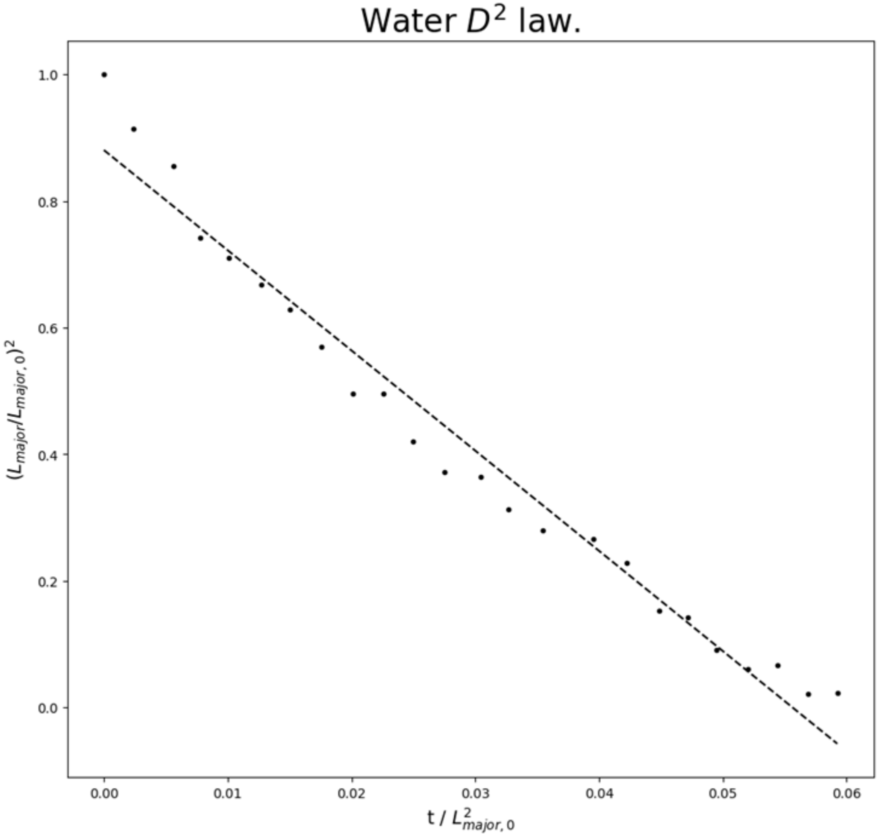
$$A_{os} = 2\pi a^2 \left(1 + \frac{1-e^2}{2e} \ln\left(\frac{1+e}{1-e}\right)\right)$$

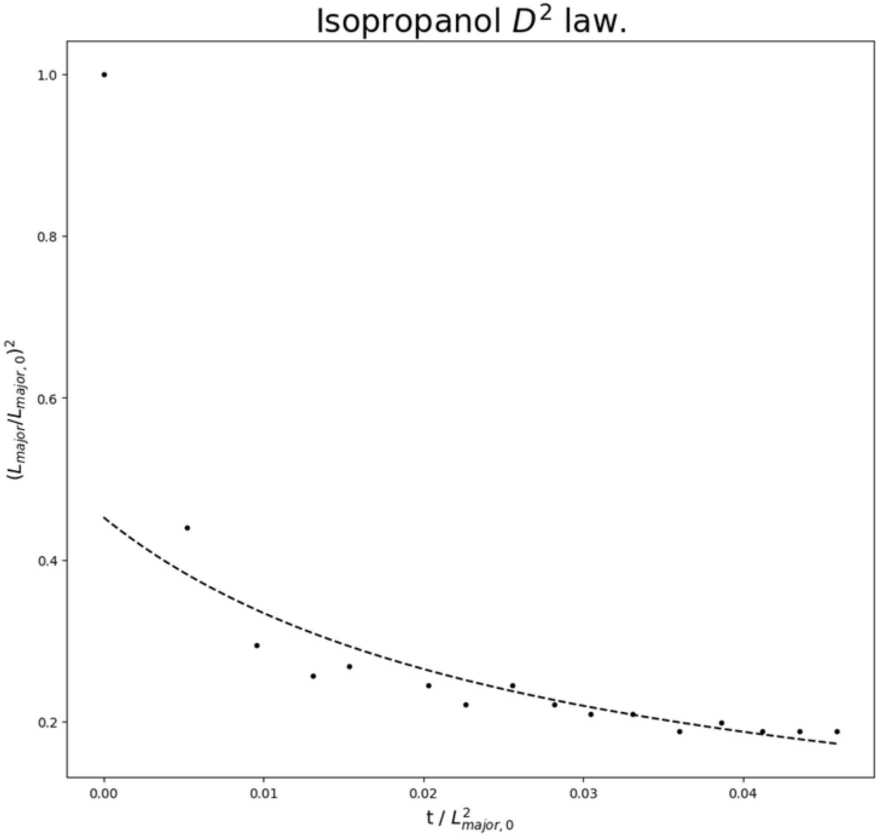
$$V_{os} = \frac{1}{6}\pi \cdot A_R \cdot L_{major}^3$$



Width (Water)
Height (Water)
Width (Iso)
Height (Iso)
% of initial Length [px]
Time [s]
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400


A vs t.
Water
Water Fit
Isopropanol
Ln(A) vs t.
Water
Isopropanol
$\frac{1}{A}$ vs t.
Water
Isopropanol
Isopropanol Fit


Water D^2 law.
$(L_{major}/L_{major,0})^2$
t / $L^2_{major,0}$
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06


Isopropanol D^2 law.
$(L_{major}/L_{major,0})^2$
t / $L^2_{major,0}$
1.0
0.8
0.6
0.4
0.2
0.00
0.01
0.02
0.03
0.04

Results

- The evaporation of oblate droplets is similar to the acoustically driven evaporation of spherical droplets.

- Water behaves as expected in our experiments.

- Isopropanol does not follow expectations.

Conclusions

- Our project was successful at capturing data for mass transfer
  - We would recommend use for Junior Lab

- Our project was successful at showing wave basics
  - We would recommend use for K-12

- Improvements?
  - Better study of mass transfer by experts
  - Print sides to apparatus to reduce wind flow
  - Take pictures of shadow, not fluid

Sources

- Marzo, A., Barnes, A. C., & Drinkwater, B. W. (2017). TinyLev: A multi-emitter single-axis acoustic levitator. *Review of Scientific Instruments*, *88*(8), 085105. https://doi.org/10.1063/1.4989995.
- Zang, D., Yu, Y., Chen, Z., Li, X., Wu, H., & Geng, X. (2017). Acoustic levitation of liquid drops: Dynamics, manipulation and phase transitions. *Advances in colloid and interface science*, *243*, 77-85. Acoustic levitation of liquid drops: Dynamics, manipulation and phase transitions - PubMed (nih.gov)
- Belal Al Zaitone, Oblate spheroidal droplet evaporation in an acoustic levitator, International Journal of Heat and Mass Transfer, Volume 126, Part B, 2018, Pages 164-172, ISSN 0017-9310, https://doi.org/10.1016/j.ijheatmasstransfer.2018.06.029.

Acknowledgements

University of Utah’s Chemical Engineering Department

THE UNIVERSITY OF UTAH
CHEMICAL
ENGINEERING

Dr. Stacy Firth, Dr. Swomitra Mohanty, Dr. Anthony Butterfield