SOUTH CAROLINA GOVERNOR'S SCHOOL
for Science & Mathematics

Auto-ejection of Silicone Oil Droplets in Microgravity Due to Capillary Action

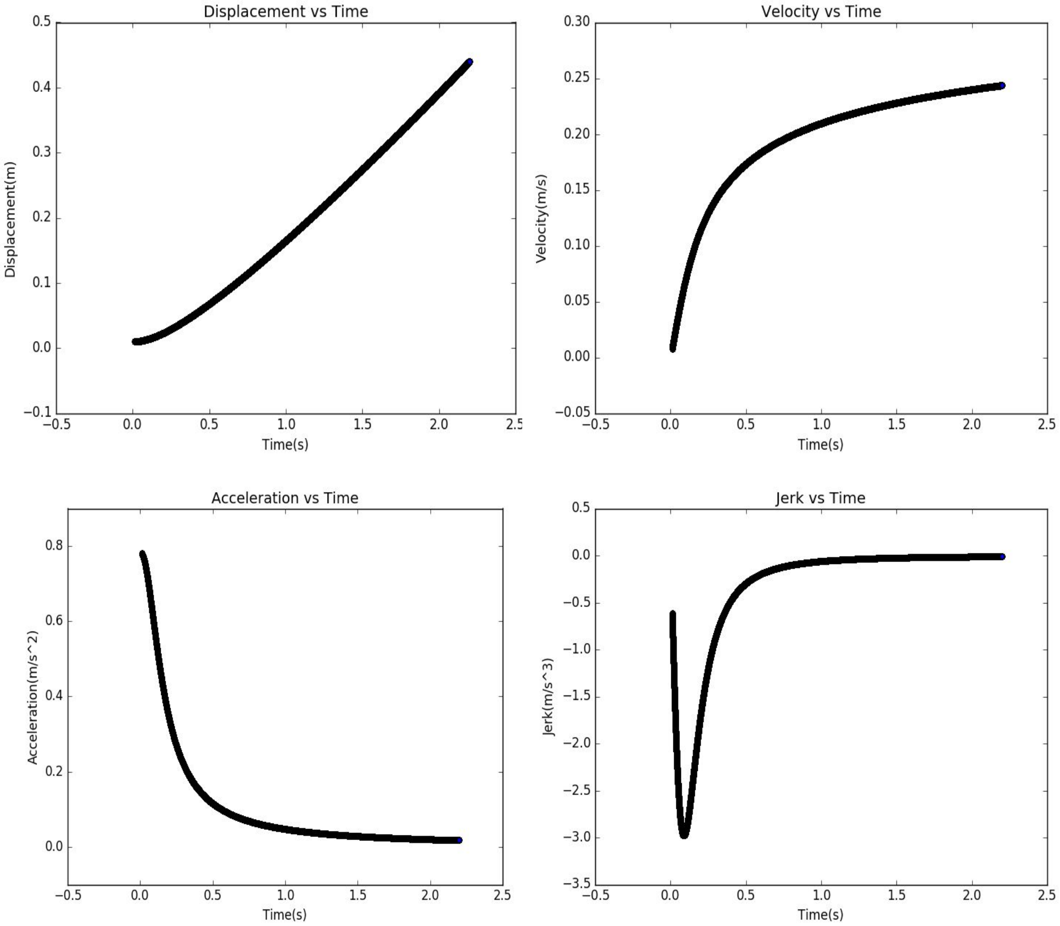
BRENNAN CAIN, GRACEN MUELLER, AND RYAN CUENTES

Overview and Goals

- Challenge/Goal:
  - NASA and ASGSR proposed a challenge to high school students to design an apparatus to to eject a silicon oil droplet as high as possible in a microgravity environment using capillary action.
- Our solution:
  - Nozzle optimized with respect to tube material type (optimizing surface energy differences), amount of tapering in the nozzle, and tube height.

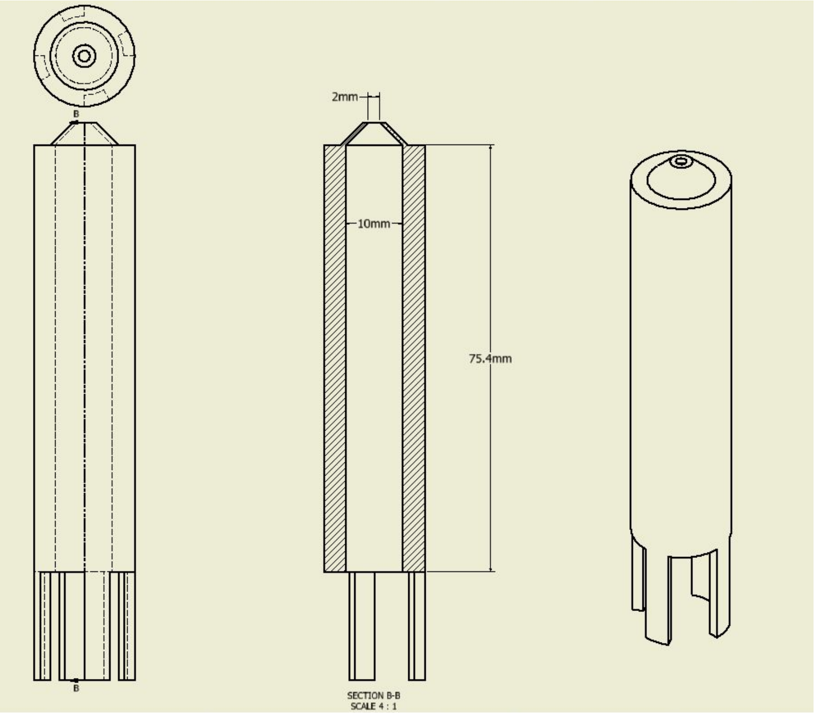
Initial Simulations

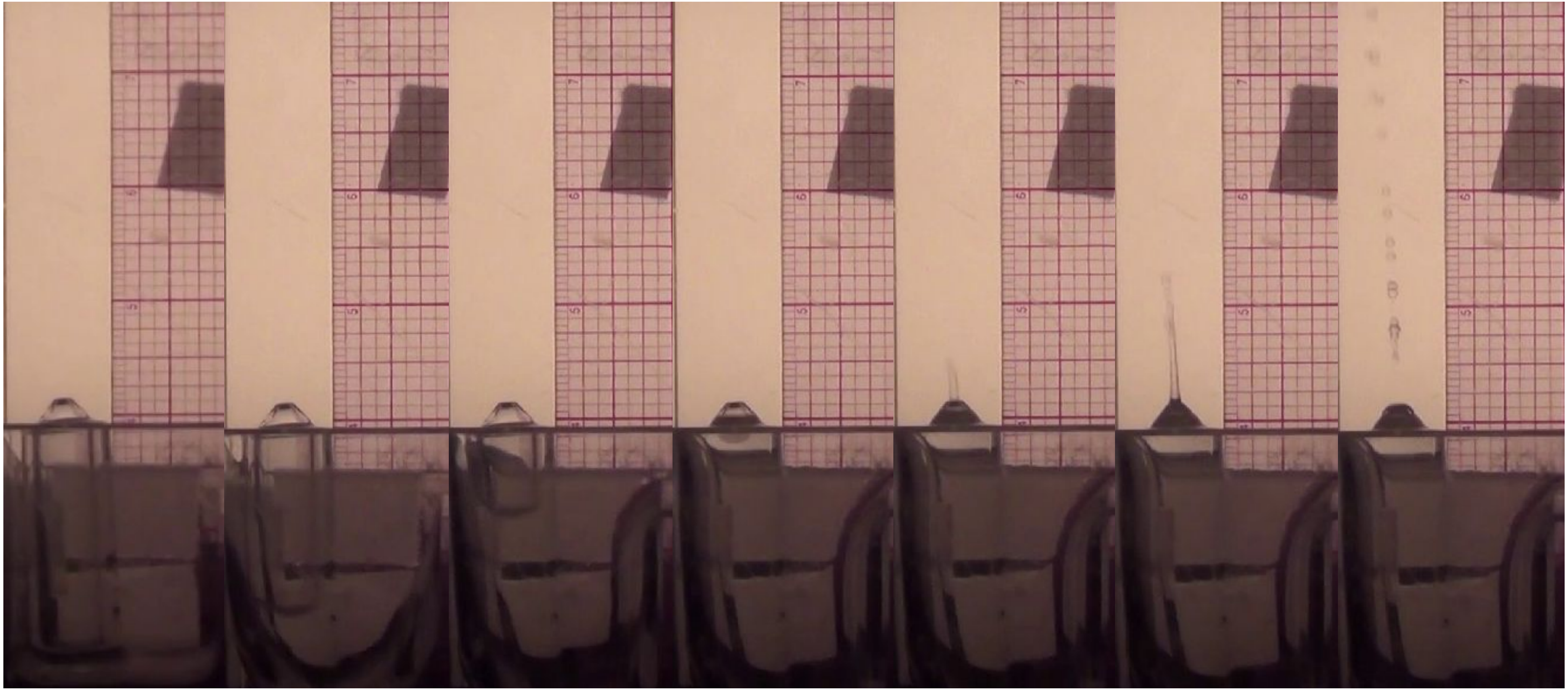
- Tube material chosen based on free energy differences.
  - Silicon Oil: Low Free Energy
  - Glass: High Free Energy
- Tube height chosen based on height vs. velocity benefit.
- Hypothesized Velocities:
  - Droplet ejection: 0.16 m/s
  - Average meniscus velocity: 0.0002 m/s
- Hypothesized droplet ejection Time: 0.4 s



Materials and Design

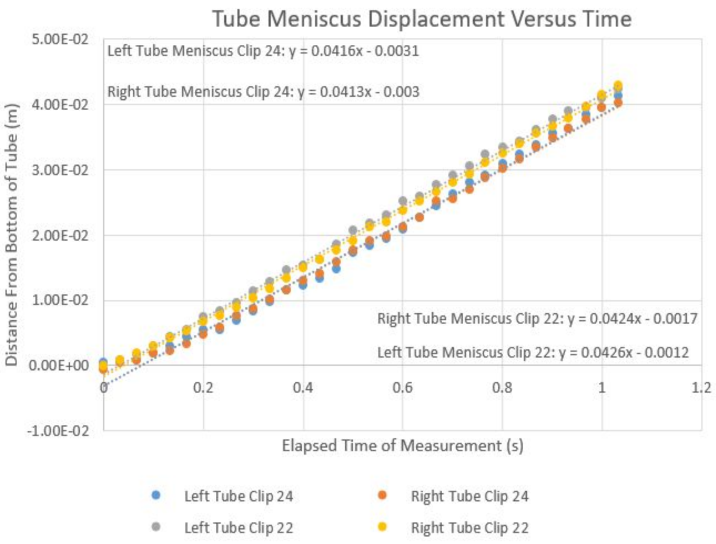
- Tower:
  - This design utilized the drop tower at the NASA Glenn Research Center, where it was dropped to experience 2.2 seconds of microgravity during freefall.
- Ejector:
  - Tube: 57 mm long, diameter of 10 mm
  - Nozzle: 4 mm long, with an inner radius tapered from 5 mm to 1 mm (45°).
  - Supports: 4 legs 19 mm long

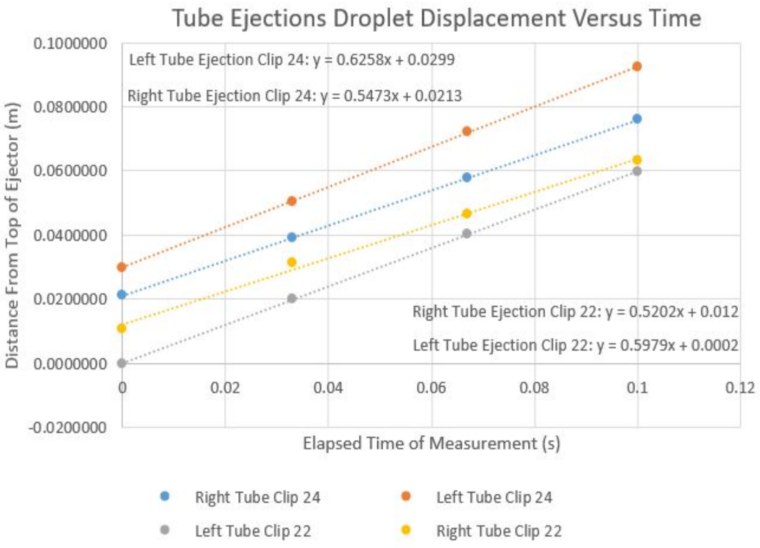




Frame 22 Frame 33 Frame 48 Frame 61 Frame 62 Frame 63 Frame 66

Results





Average meniscus velocity: 0.04198 m/s

Average droplet ejection velocity: 0.5728 m/s

Conclusions

- Device achieved successful droplet ejection
- Droplet had a much higher velocity than expected
- Possible source of error:
    - Improper models due to contact angle assumptions
        - E.g. dynamic contact angle, contact angle differences in microgravity
- Looking forward:
    - Fit models to data
    - Experiment with other variables
        - E.g. Fluids, materials, tube and nozzle radius

Citations

- Fluid Dynamics in Microgravity .:. Go Up. (n.d.). Retrieved August31,2016,from.http://tuhsphysics.ttsd.k12.or.us/Research/DIME06 /FinalPaper/index.htm
- Keller, A., Broje, V., & Setty, K. (2007). Effect of advancing velocity and fluid viscosity on the dynamic contact angle of petroleum hydrocarbons. Journal of Petroleum Science and Engineering, 58(1-2), 201-206. doi:10.1016/j.petrol.2006.12.002
- Mehrabian, H., & Feng, J. J. (2014, June 17). Auto-ejection of liquid drops from capillary tubes. J. Fluid Mech. Journal of Fluid Mechanics, 752, 670-692. doi:10.1017/jfm.2014.352
- Phaechamud, T., & Savedkairop, C. (2012, Winter). Contact Angle and Surface Tension of Some Solvents Used in Pharmaceuticals. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 3(4), 513-529. Retrieved August 26, 2016, from Faculty of Pharmacy.
- R. (2009). ThermoPore-Surface Energy & Capillary Forces, Part 4.Retrieved August 25, 2016, from.https://www.youtube.com/watch?v=sLI_JKNYXVU
- Substrates and Adhesion – Know Your Surface. (n.d.). Retrieved August 24, 2016, from.http://solutions.3m.com/wps/portal/3M/en_US/Adhesives/Tapes/Support/Technical-News-Articles/?PC_Z7_U00M8B1A00NI60IDFIPS8T3HR2000000_assetId=1319246224870
- http://www.uweb.engr.washington.edu/education/pdf/ashsurfscontact%20angles05.pdf NEED TO CITE THIS

Acknowledgements

- The GSSM Foundation for their generous support of our club and experiment.
- NASA and ASGSR for hosting this challenge and allowing us to participate.
- Dr. Al DeGennaro and Dr. David Whitbeck for their mentorship and support.
- Dr. Elaine Parshall for prototyping and printing

SOUTH CAROLINA GOVERNOR'S SCHOOL
for Science & Mathematics

Auto-ejection of Silicone Oil Droplets in Microgravity Due to Capillary Action

BRENNAN CAIN, GRACEN MUELLER, AND RYAN CUENTES