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## Viscous Fluid in a Horizontally Rotating Cylinder

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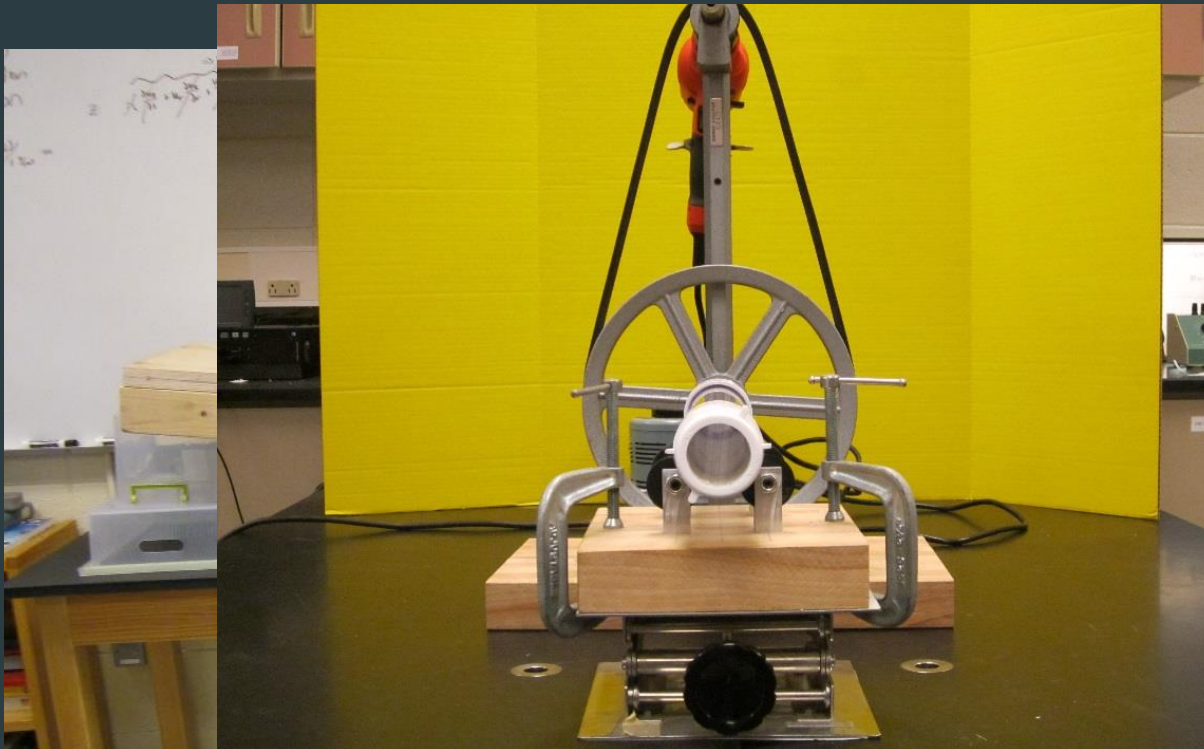
# Viscous Fluid in a Horizontally Rotating Cylinder

Researchers: Kolter Bradshaw, Zach Van Engen

Mentor: Dr. John Zwart

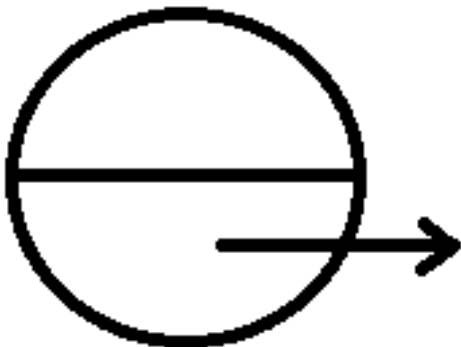
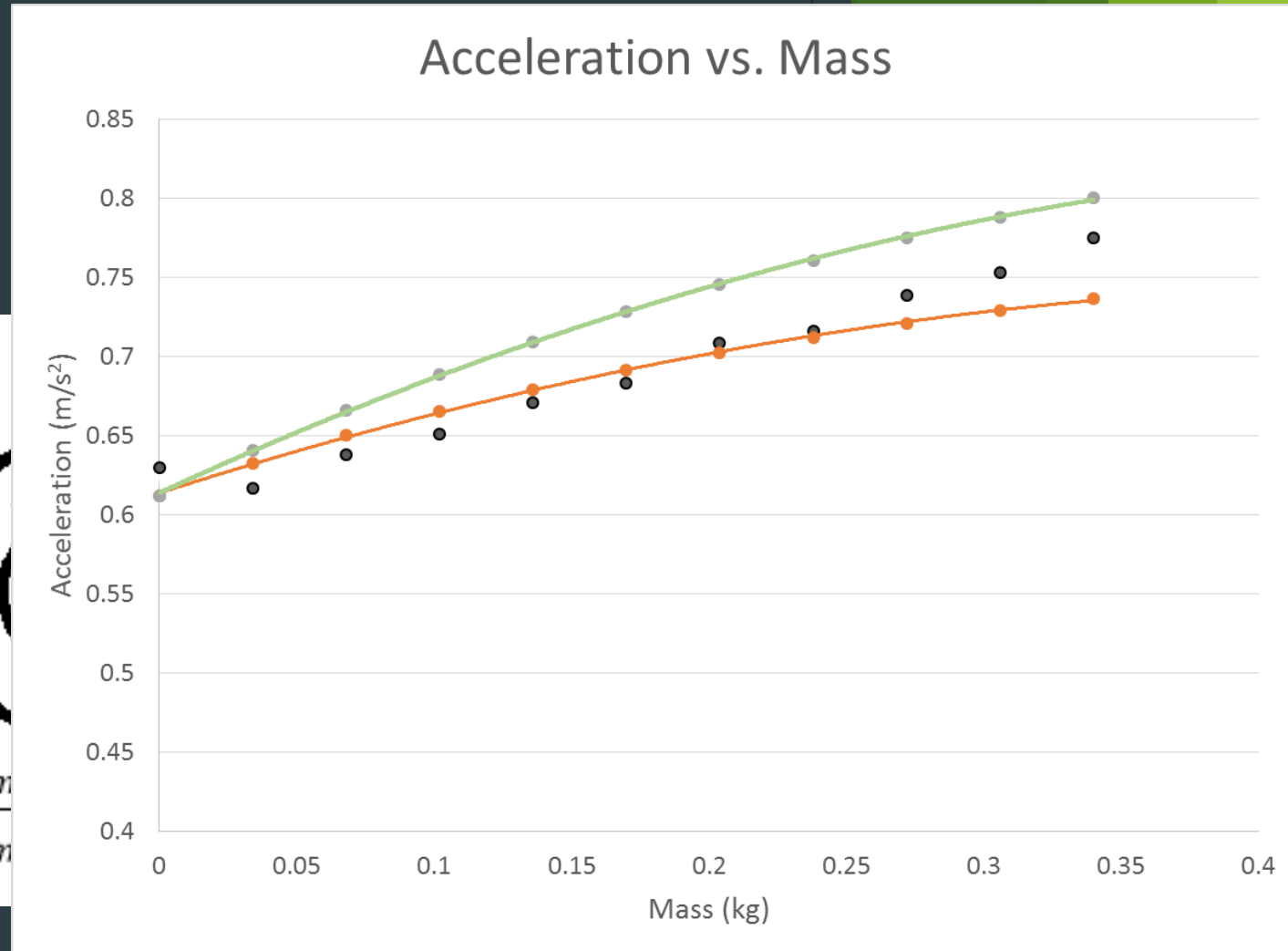
# Background

- ▶ Hoop vs. Disk
- ▶ Experimental setup
- ▶ Construction of Drill Apparatus



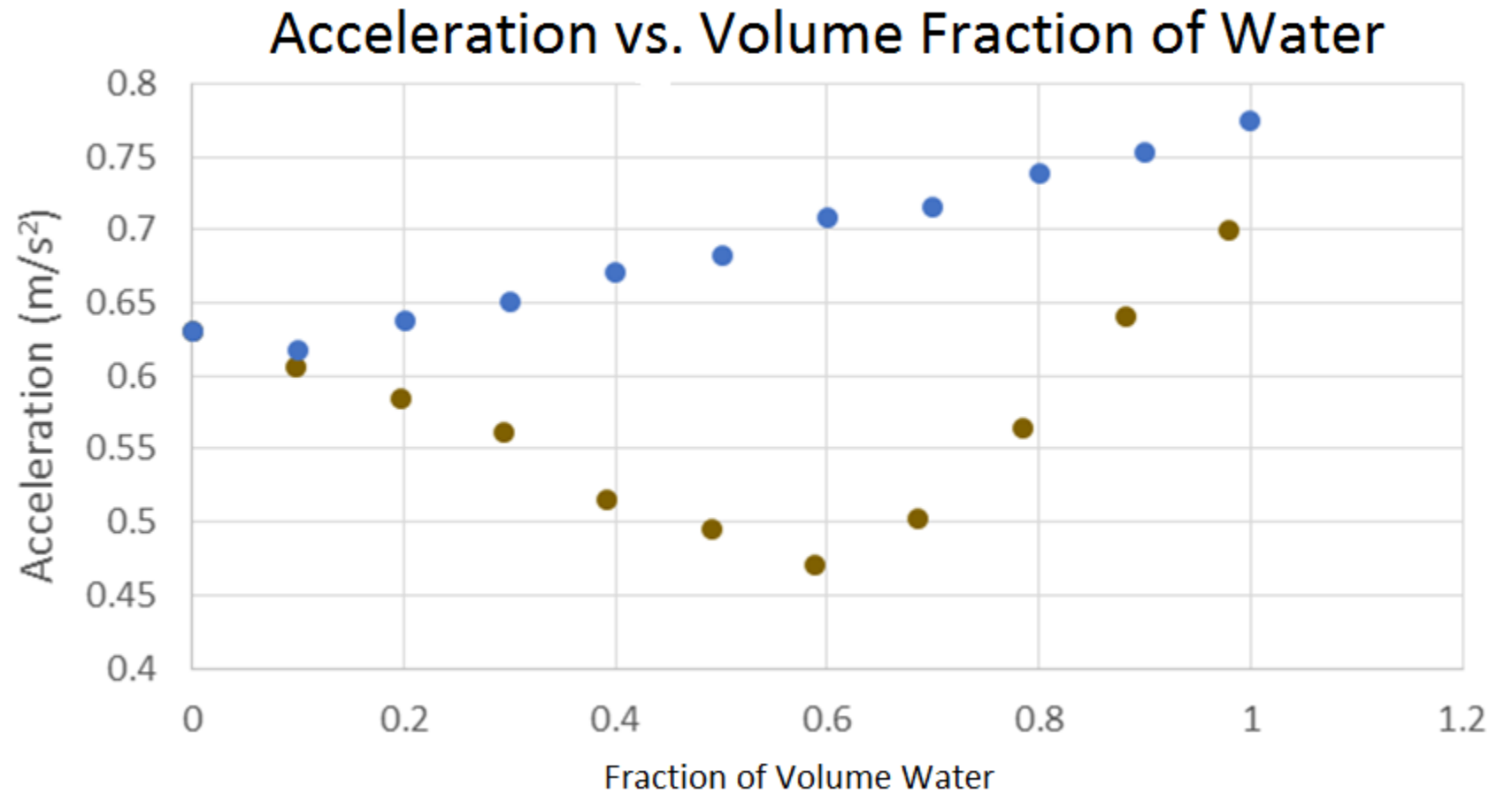
# Non-viscous Liquid

- ▶ Translating or Rotating?
- ▶ Acceleration dependent on fluid motion


$$a_{tran} = \frac{m_{tot}gR_{out}^2 \sin\theta}{I_{cyl} + m_{tot}R_{out}^2}$$
$$a_{rot} = \frac{n}{I_{cyl} + n}$$


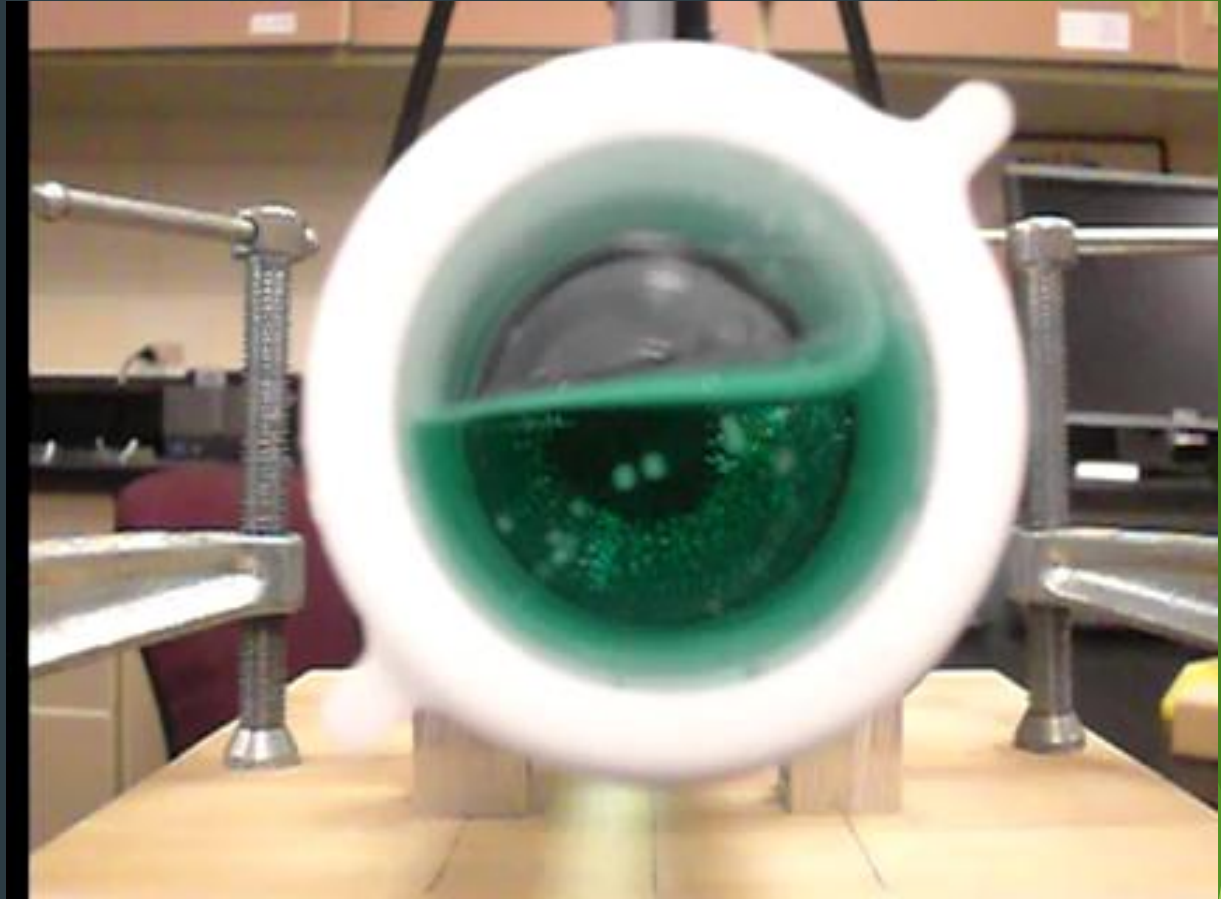
# Viscous Liquid

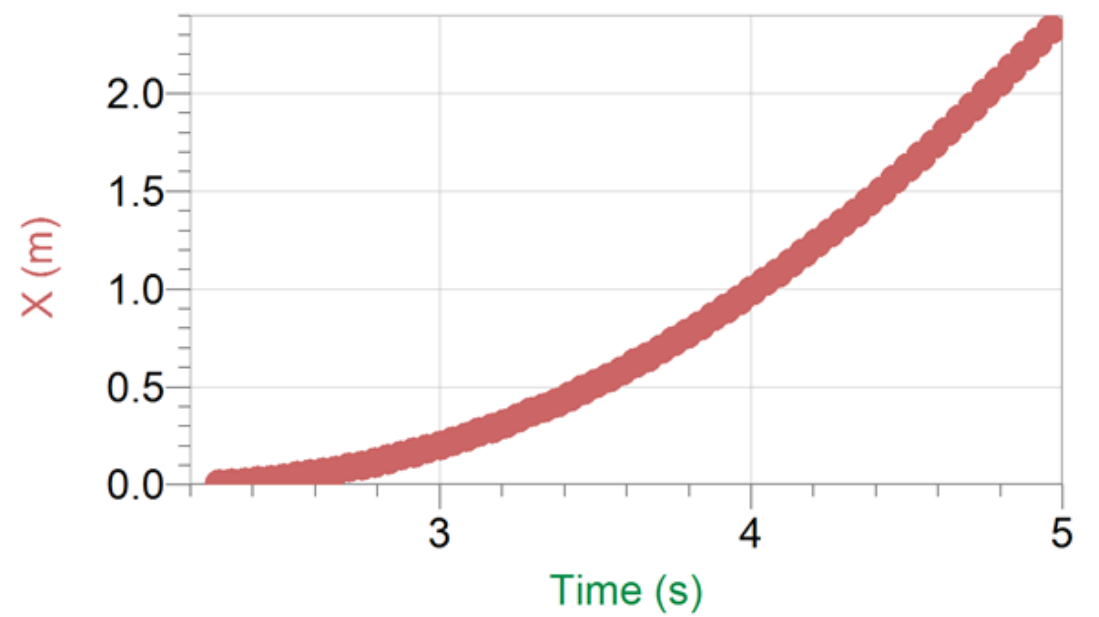
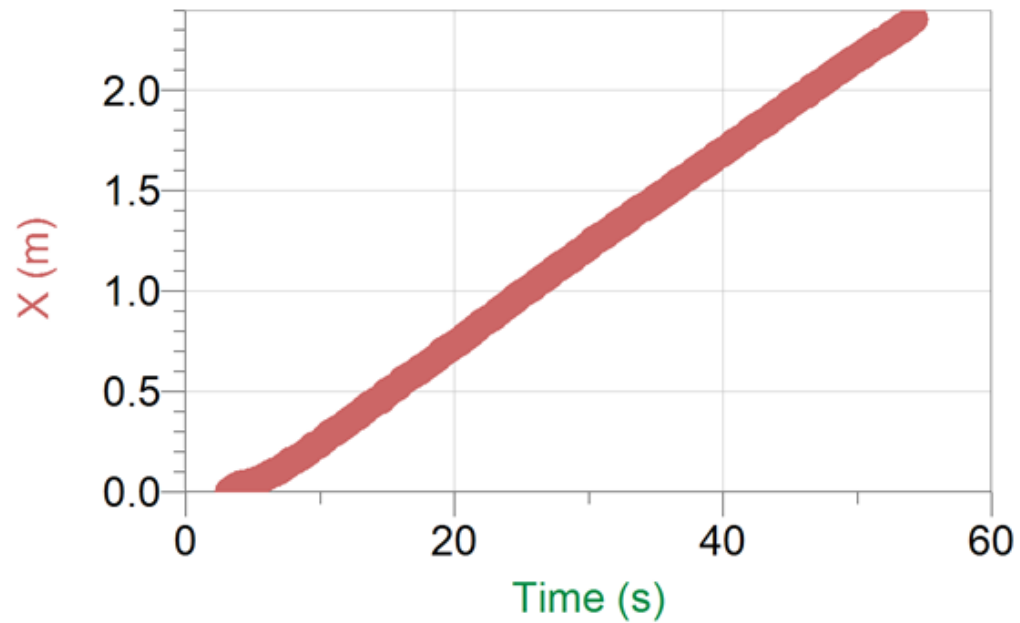
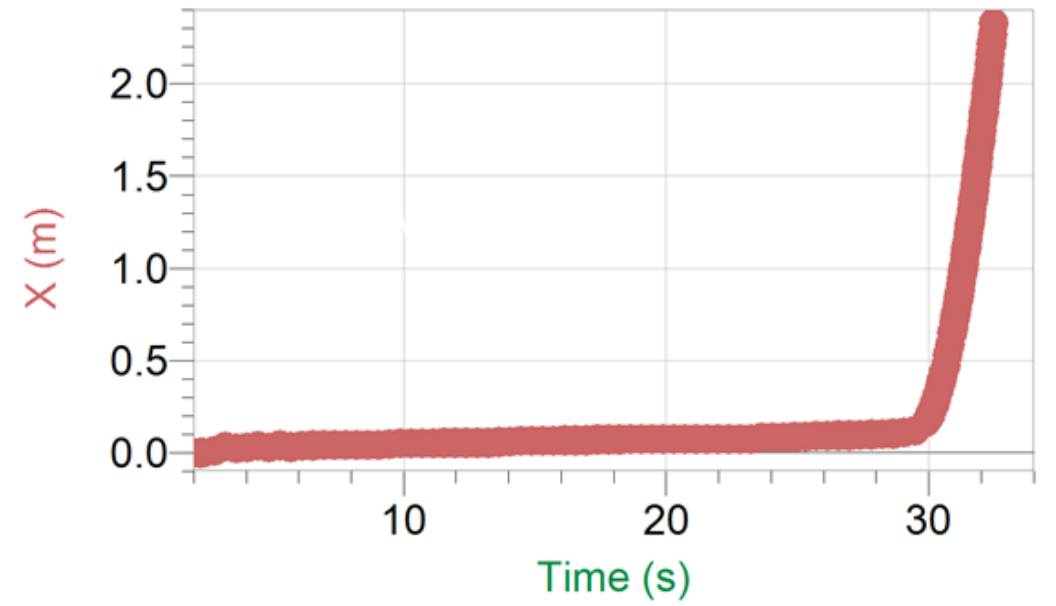
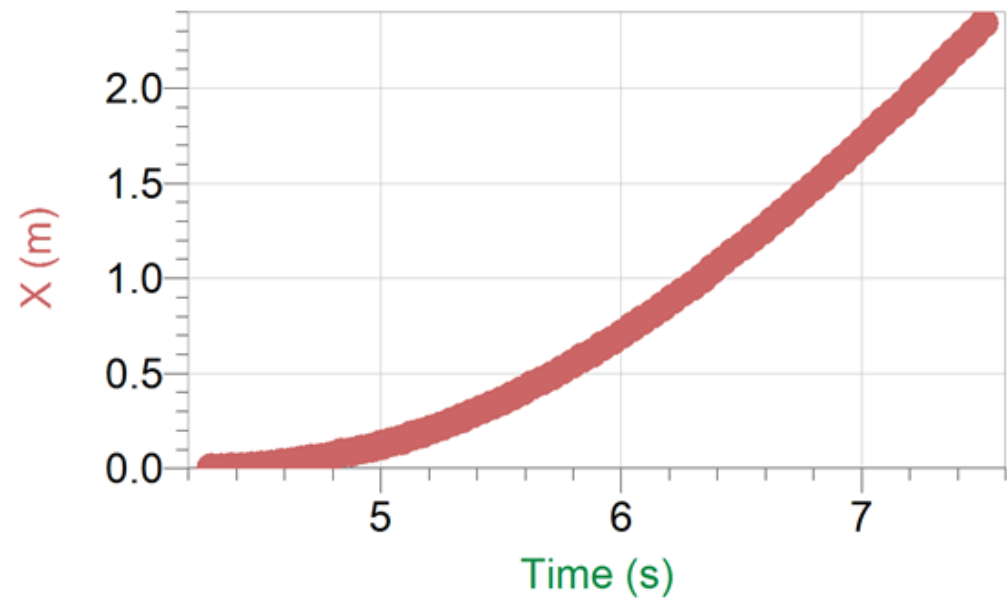
- ▶ Water vs. Glycerin
- ▶ Equations break down



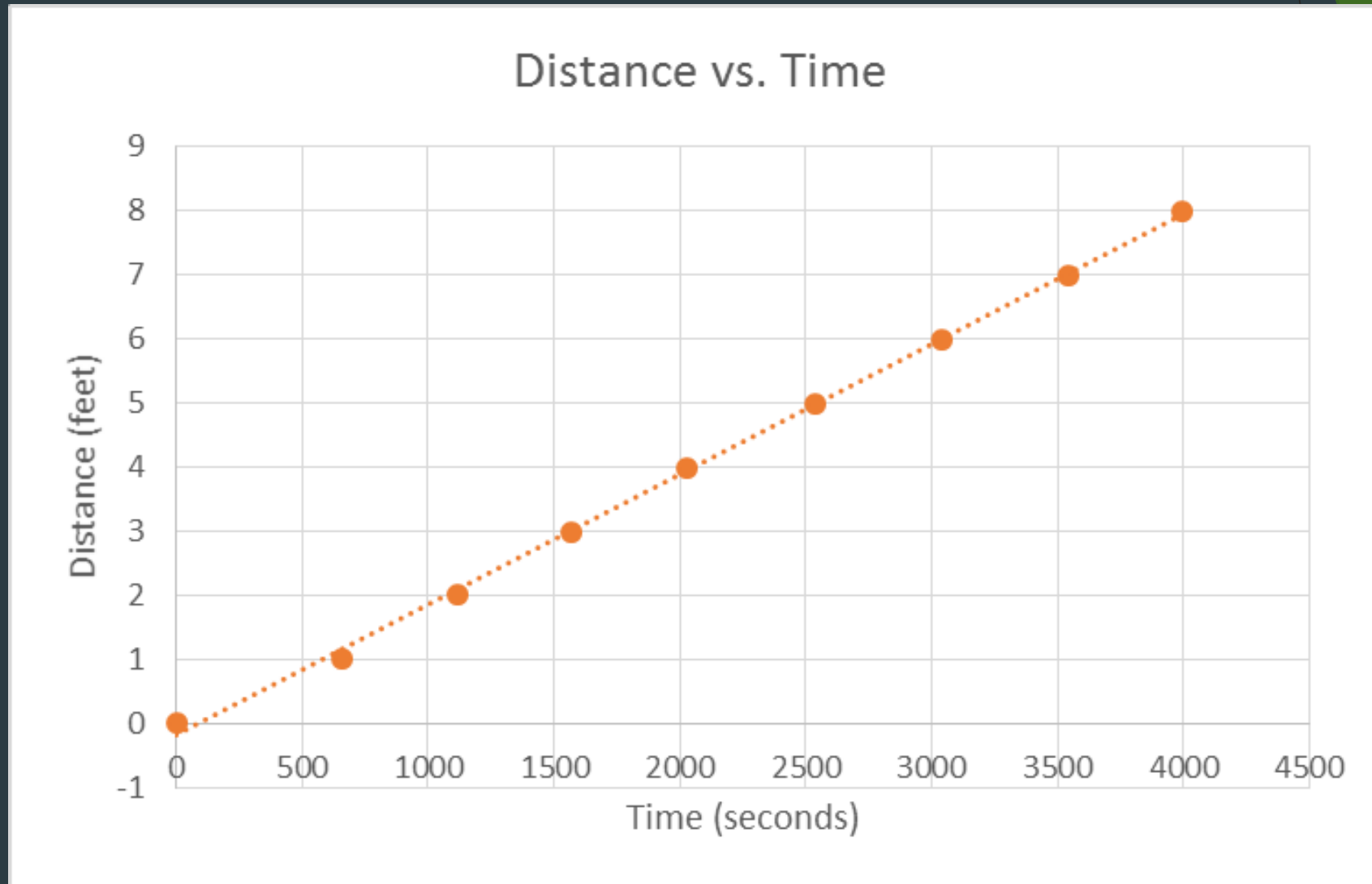
# What's Changed?

- ▶ Change of shape
- ▶ Center of Mass offset
- ▶ Rotation within itself





# Corn Syrup





# Analysis and Modeling

- ▶ How to model motion?
  - ▶ Navier-Stokes
  - ▶ Beads
- ▶ Uncertainties

(r-direction)

$$\rho \left( v_r \frac{\partial v_r}{\partial r} + \frac{v_\theta \partial v_r}{r \partial \theta} - \frac{v_\theta^2}{r} + v_z \frac{\partial v_r}{\partial z} \right) = -\frac{\partial P}{\partial r} + \rho g_r + \mu \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial v_r}{\partial r} \right) - \frac{v_r}{r^2} + \frac{\partial^2 v_r}{r^2 \partial \theta^2} - \frac{2 \partial v_\theta}{r^2 \partial \theta} + \frac{\partial^2 v_r}{\partial z^2} \right]$$

( $\theta$ -direction)

$$\rho \left( v_r \frac{\partial v_\theta}{\partial r} + \frac{v_\theta \partial v_\theta}{r \partial \theta} + \frac{v_r v_\theta}{r} + v_z \frac{\partial v_\theta}{\partial z} \right) = -\frac{1}{r} \frac{\partial P}{\partial \theta} + \rho g_\theta + \mu \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial v_\theta}{\partial r} \right) - \frac{v_\theta}{r^2} + \frac{\partial^2 v_\theta}{r^2 \partial \theta^2} + \frac{2 \partial v_r}{r^2 \partial \theta} + \frac{\partial^2 v_\theta}{\partial z^2} \right]$$

(z-direction)

$$\rho \left( v_r \frac{\partial v_z}{\partial r} + \frac{v_\theta \partial v_z}{r \partial \theta} + v_z \frac{\partial v_z}{\partial z} \right) = -\frac{\partial P}{\partial z} + \rho g_z + \mu \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial v_z}{\partial r} \right) + \frac{\partial^2 v_z}{r^2 \partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2} \right]$$

# Acknowledgments

- ▶ John Zwart
- ▶ Ben Saarloos
- ▶ Ethan Brue
- ▶ Jenni Breems
- ▶ Tim Martin

Q & A