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Viscous Fluid in a Horizontally Rotating Cylinder

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Viscous Fluid in a Horizontally Rotating Cylinder

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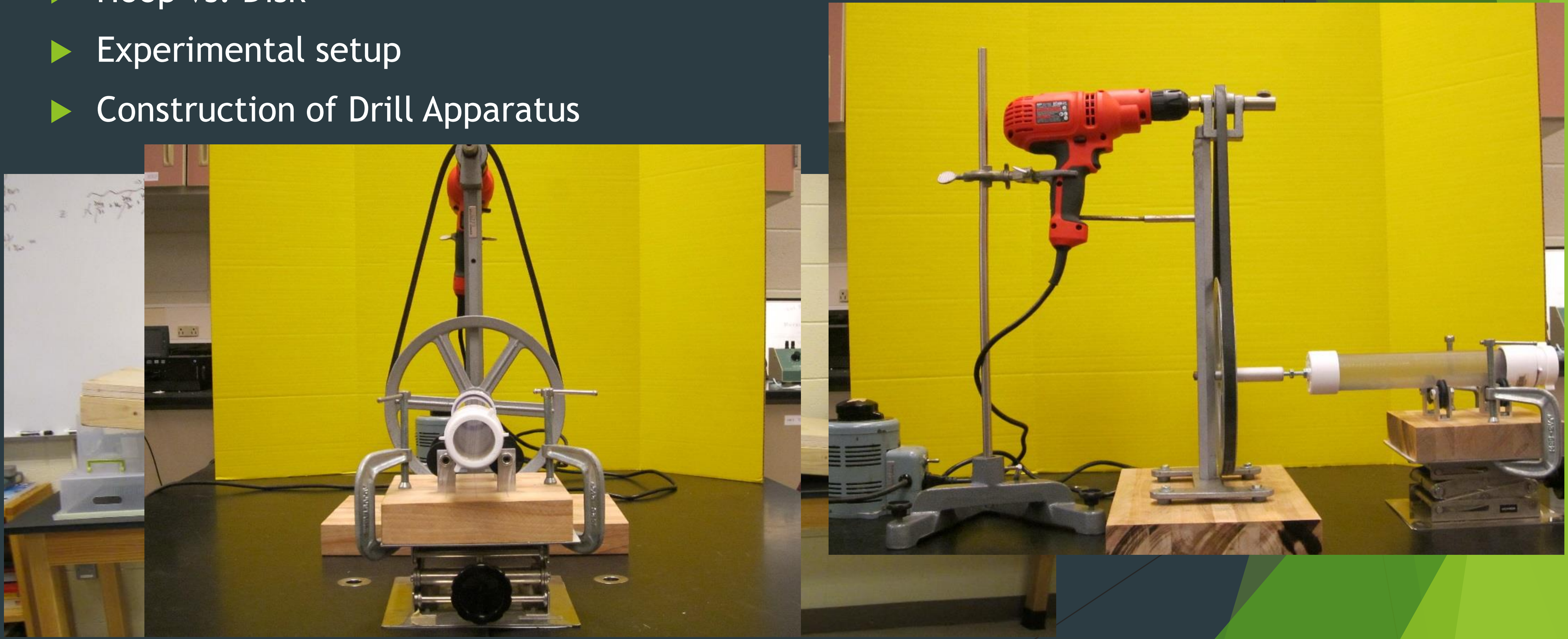
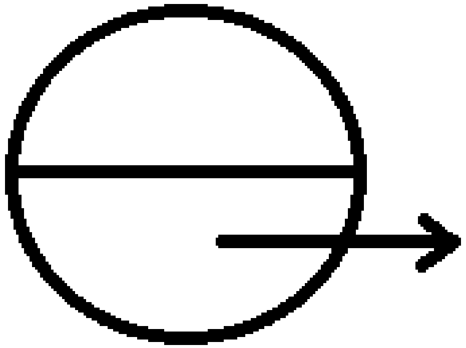
Background

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

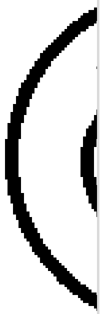


Non-viscous Liquid

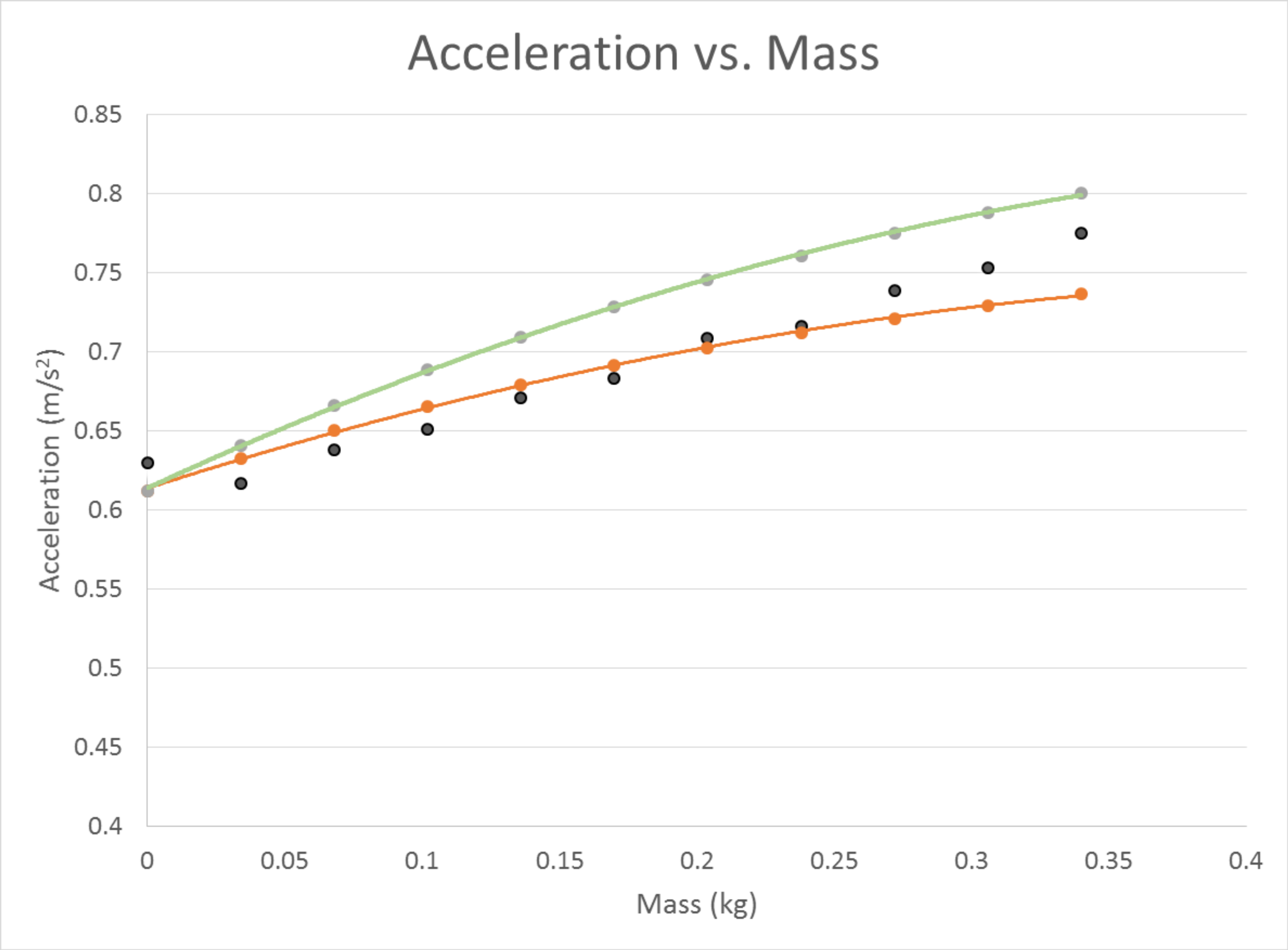
- Translating or Rotating?
- Acceleration dependent on fluid motion



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

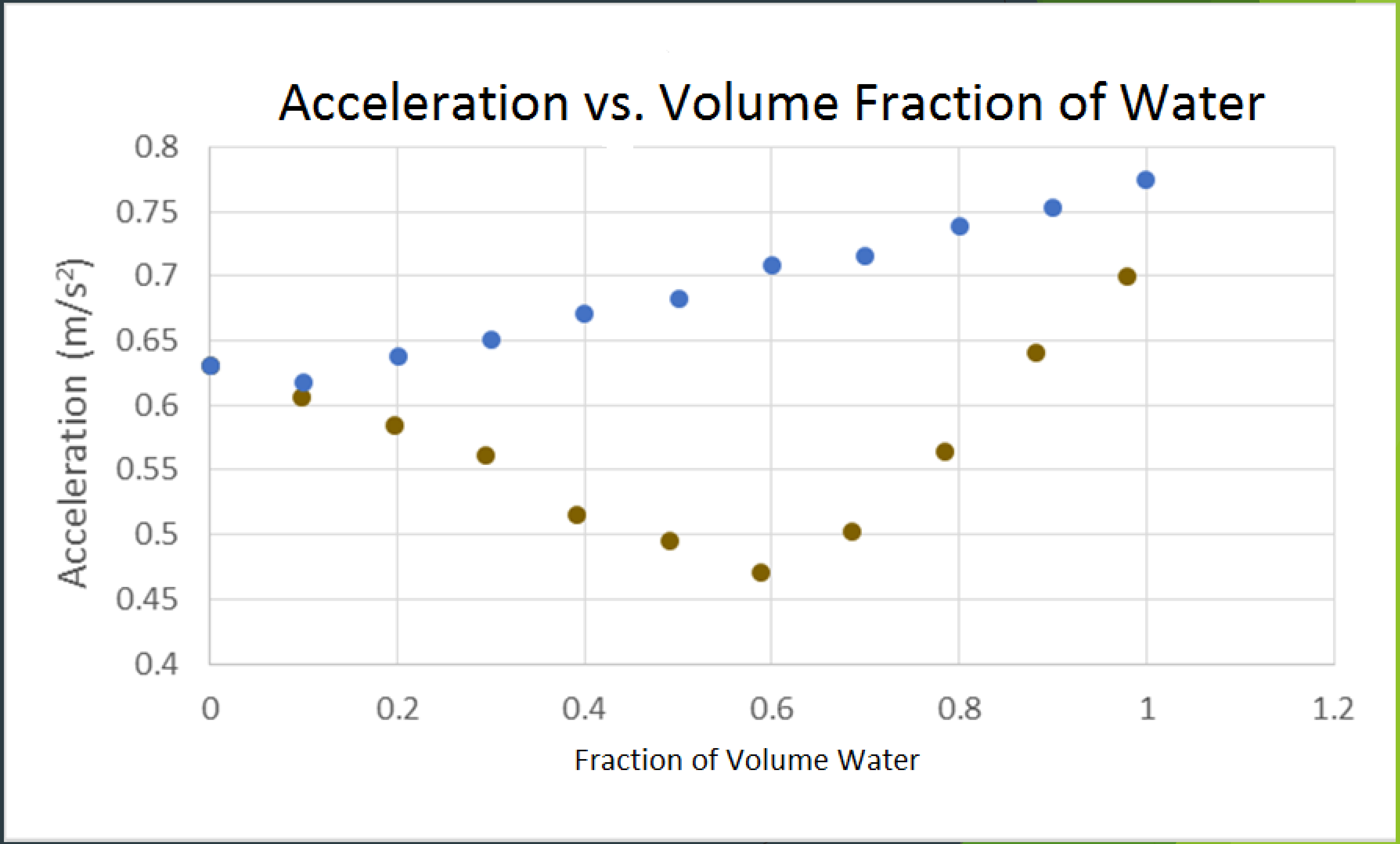


$$a_{rot} =$$



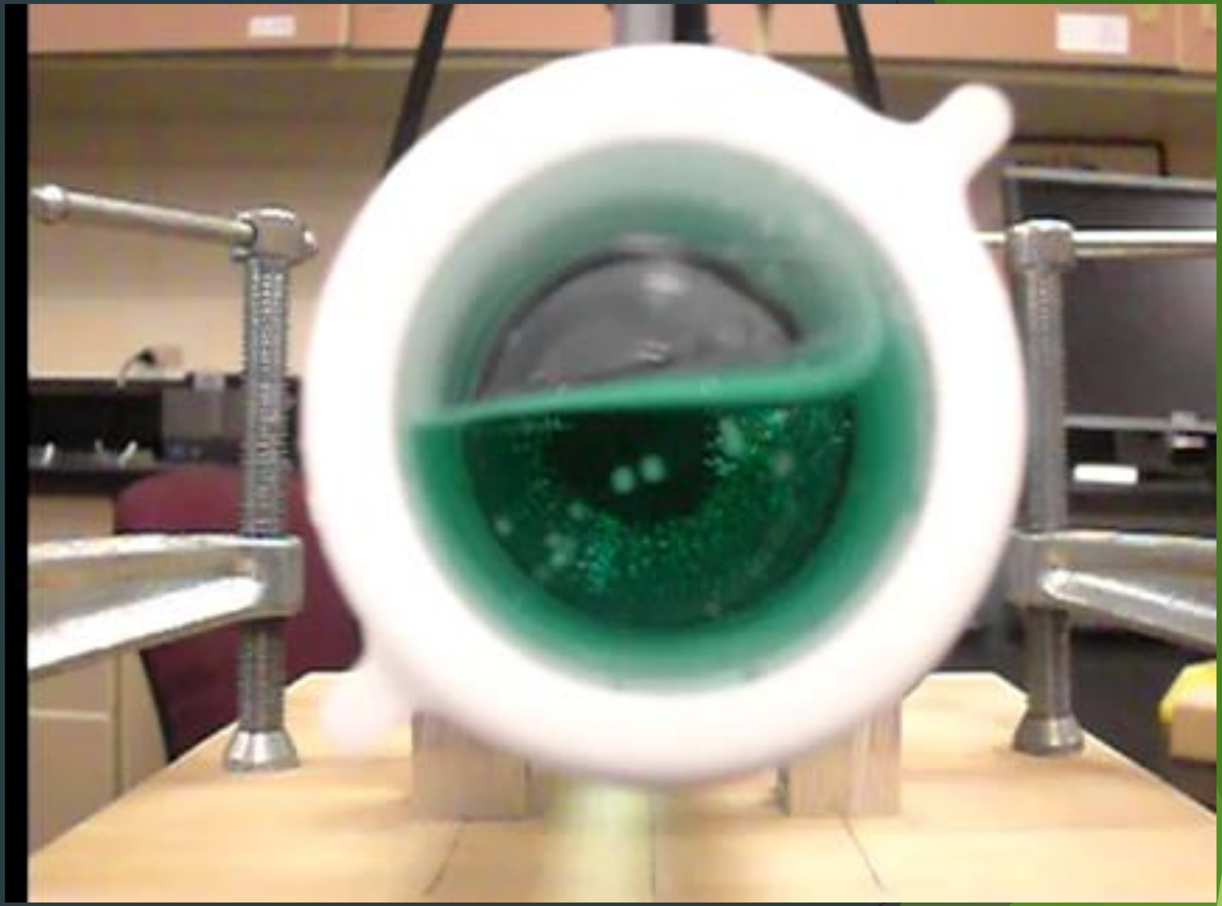
Viscous Liquid

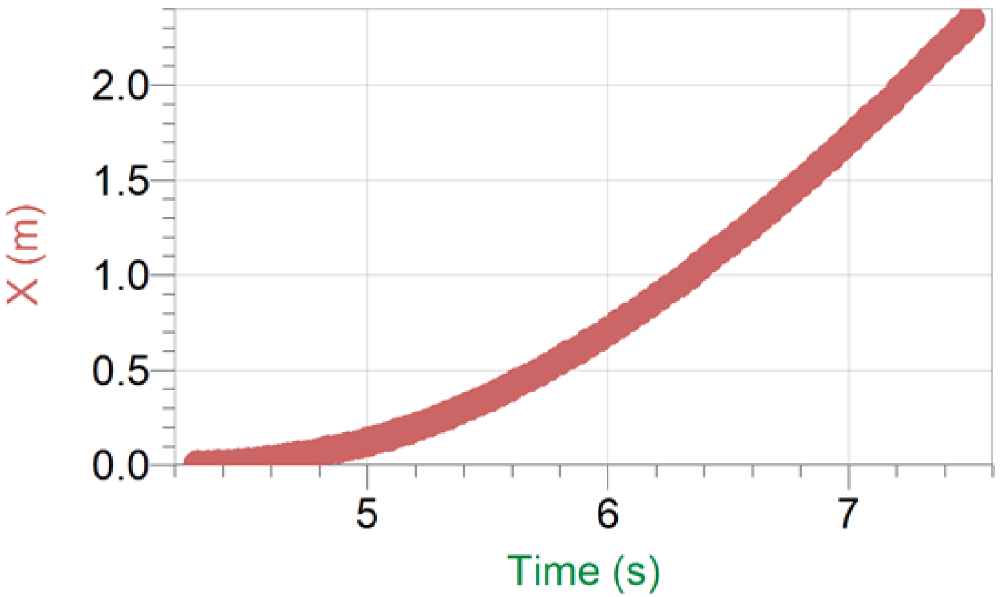
- Water vs. Glycerin
- Equations break down

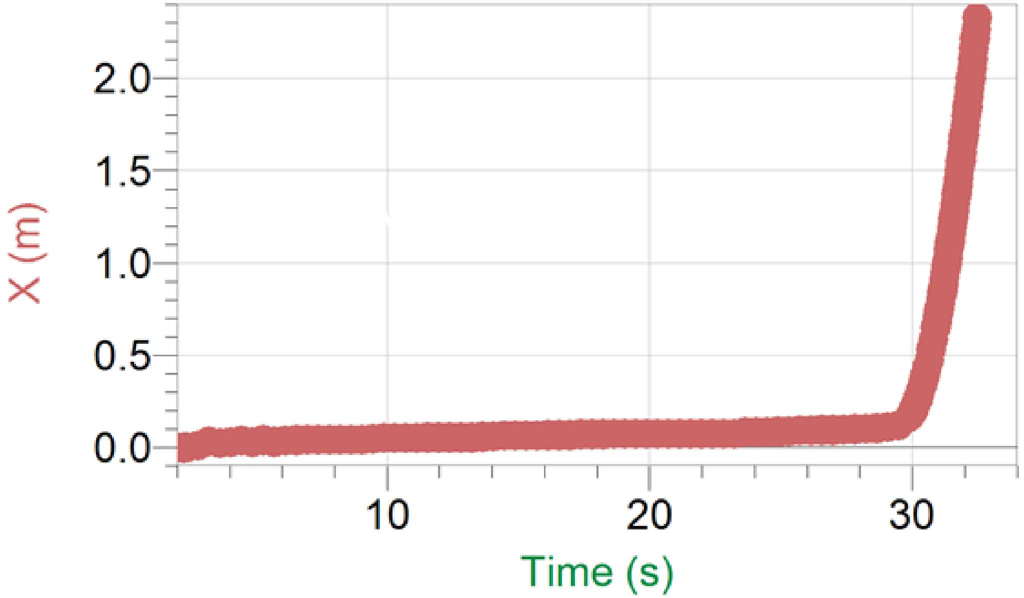


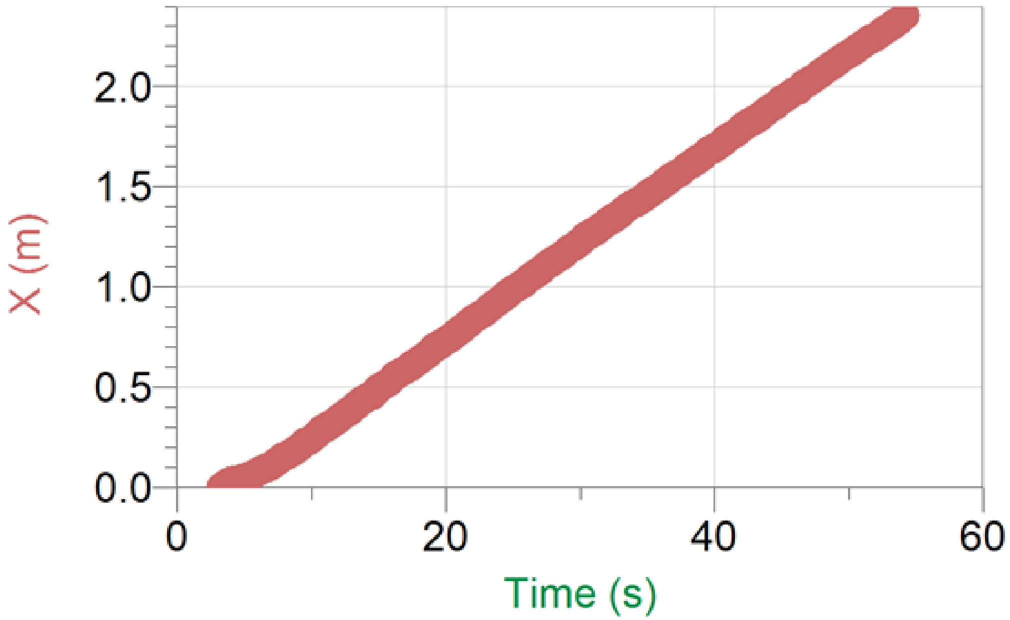
What’s Changed?

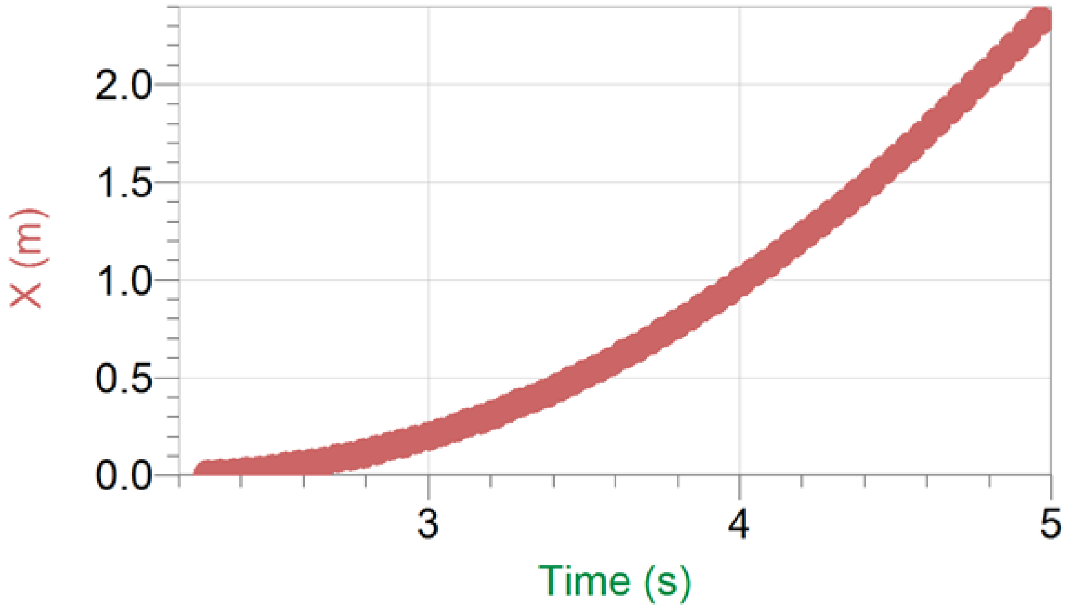
- Change of shape
- Center of Mass offset
- Rotation within itself




X (m)
2.0
1.5
1.0
0.5
0.0
5
6
7
Time (s)

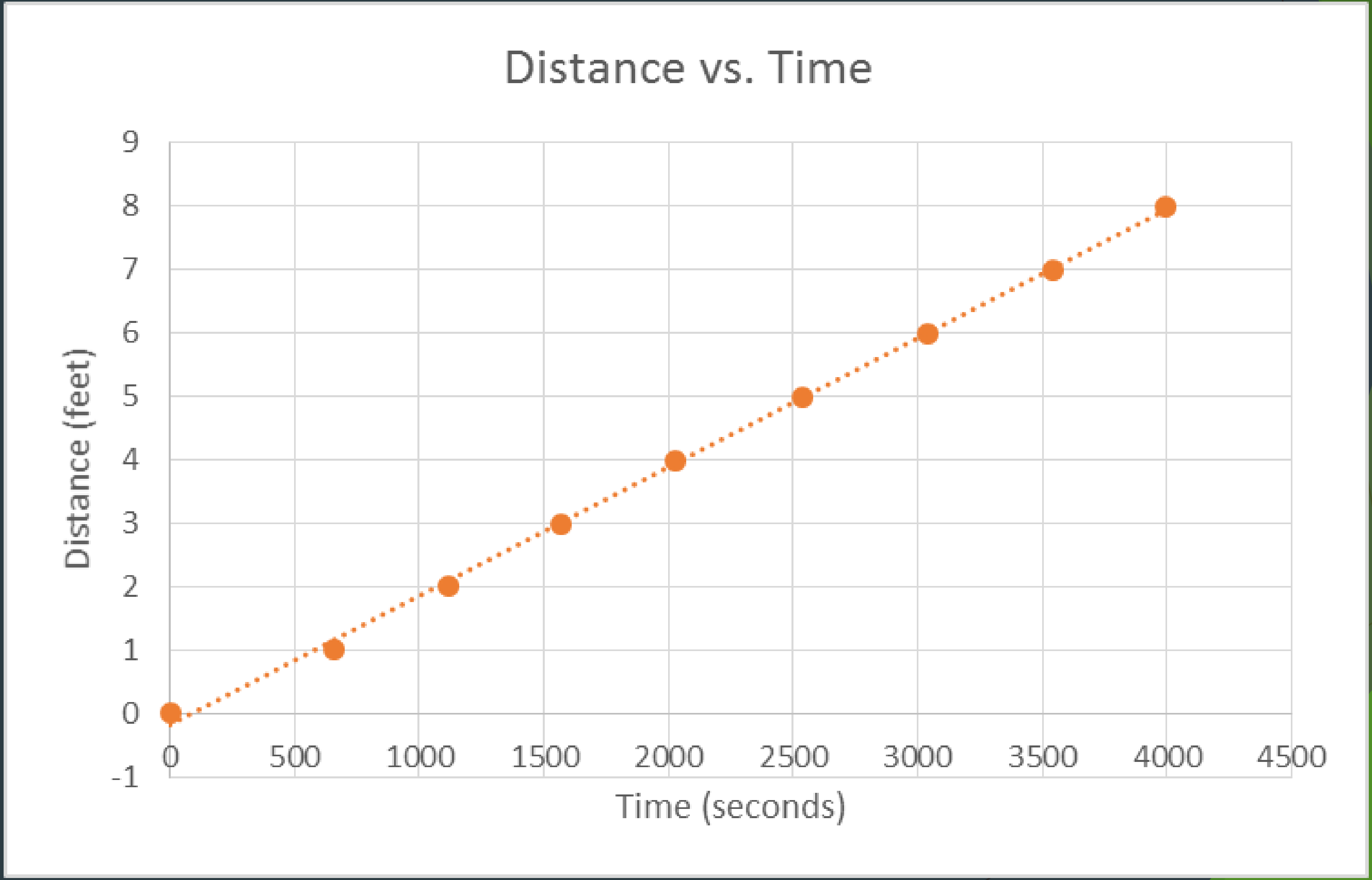

X (m)
2.0
1.5
1.0
0.5
0.0
10
20
30
Time (s)


X (m)
2.0
1.5
1.0
0.5
0.0
0
20
40
60
Time (s)


X (m)
2.0
1.5
1.0
0.5
0.0
3
4
5
Time (s)


5

Corn Syrup


Distance vs. Time
Distance (feet)
9
8
7
6
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (seconds)

Analysis and Modeling

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

(r-direction)

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

(θ-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

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Q & A