Team Brazil – University of Campinas

#01: Cummulative Cannon

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Problem Statement

How high may a ping pong ball jump using the setup on the video.

What is the **maximal fraction** of the total **kinetic energy** that can be **transferred** to the ball?

Disclaimer

We have not **solved** this problem, but we are confident that some of our results can trigger a discussion.

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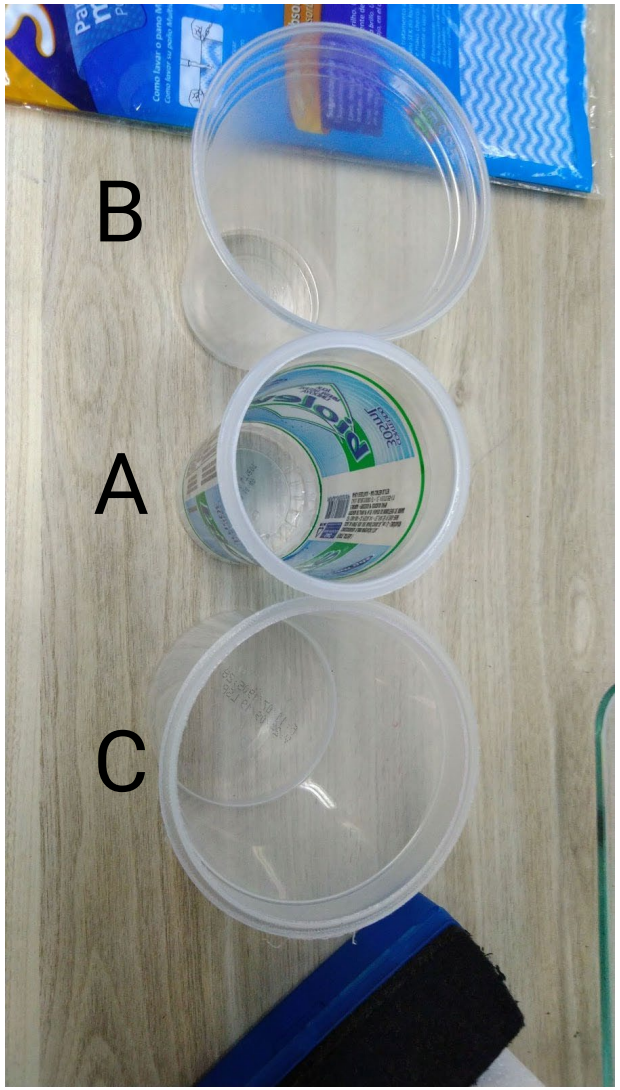
Chapter 1 - The Experiment: Setup

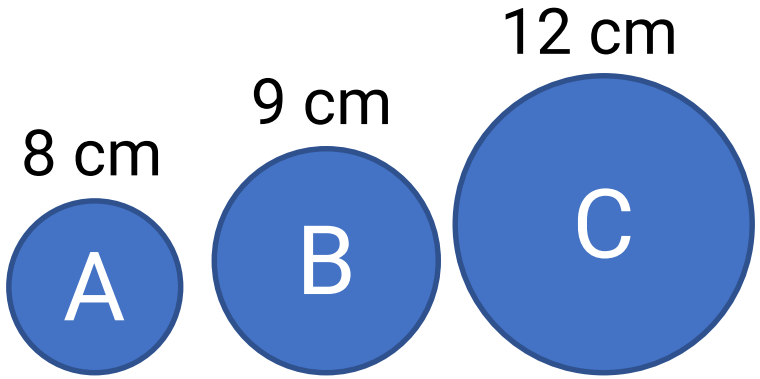
$m_b = 2.7g$

$d_{ball} = 40mm$



Chapter 1- The Experiment: Studied Parameters

Up to 7 different amounts of water per cup.

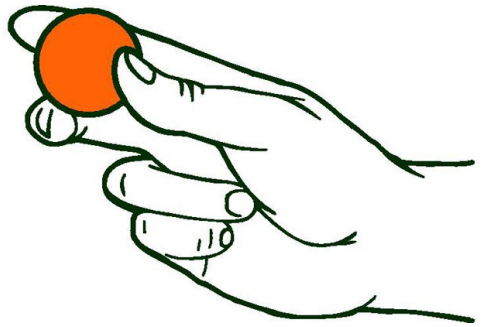


3 Different Cup Diameters.

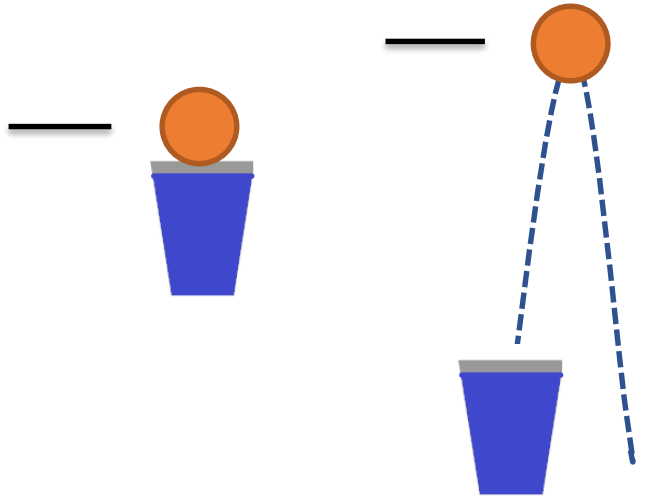
~ 1 shape

Chapter 1- The Experiment: Protocol

Slight swirl prior to throw



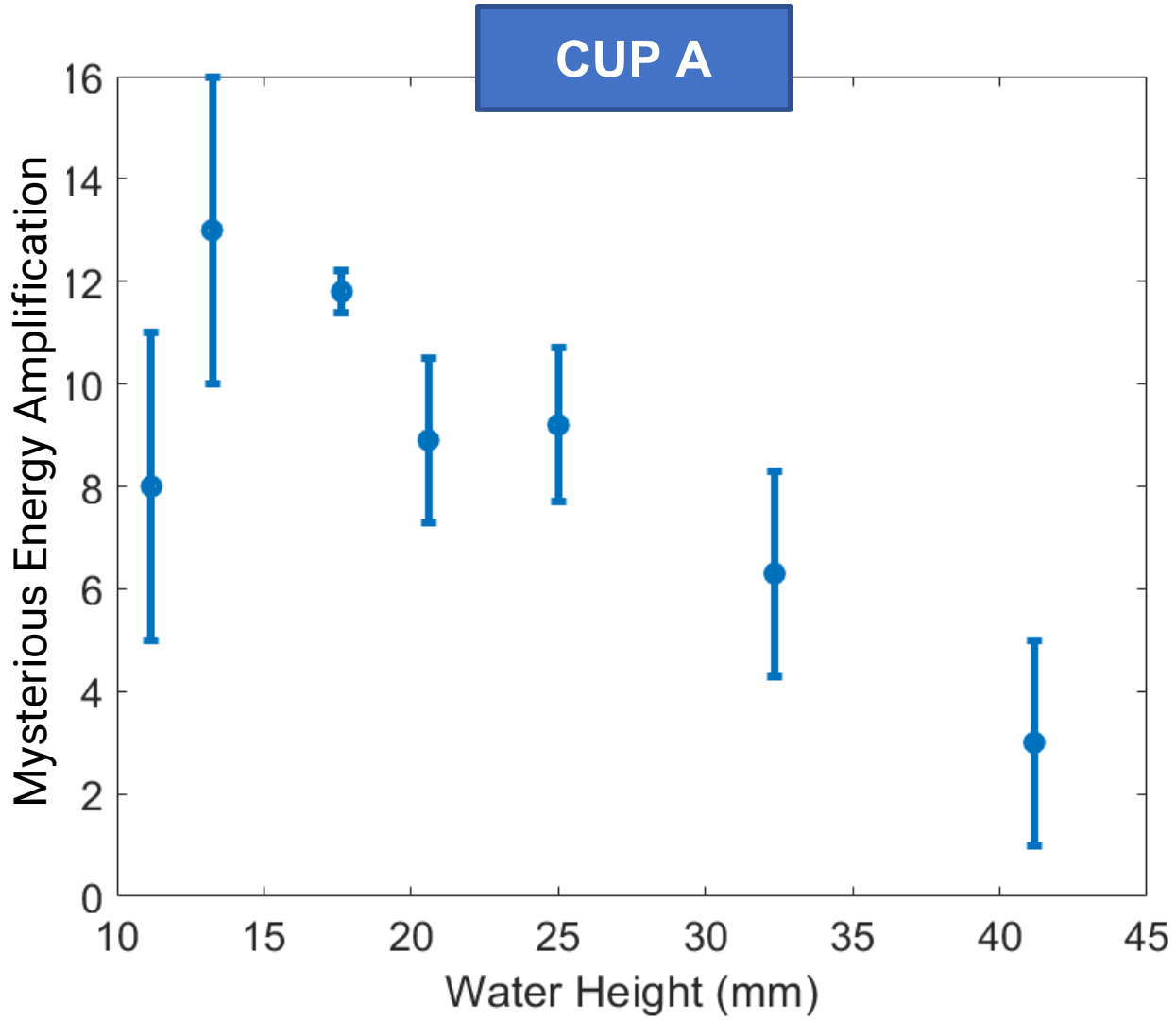
At least 5 throws per cup / water ammount



Calculate **Transferred Energy**

Mysterious Energy Amplification = $\frac{\text{Final Potential Energy of System}}{\text{Initial Potential Energy of System}}$

Chapter 2- Results: Finding trends for cup A



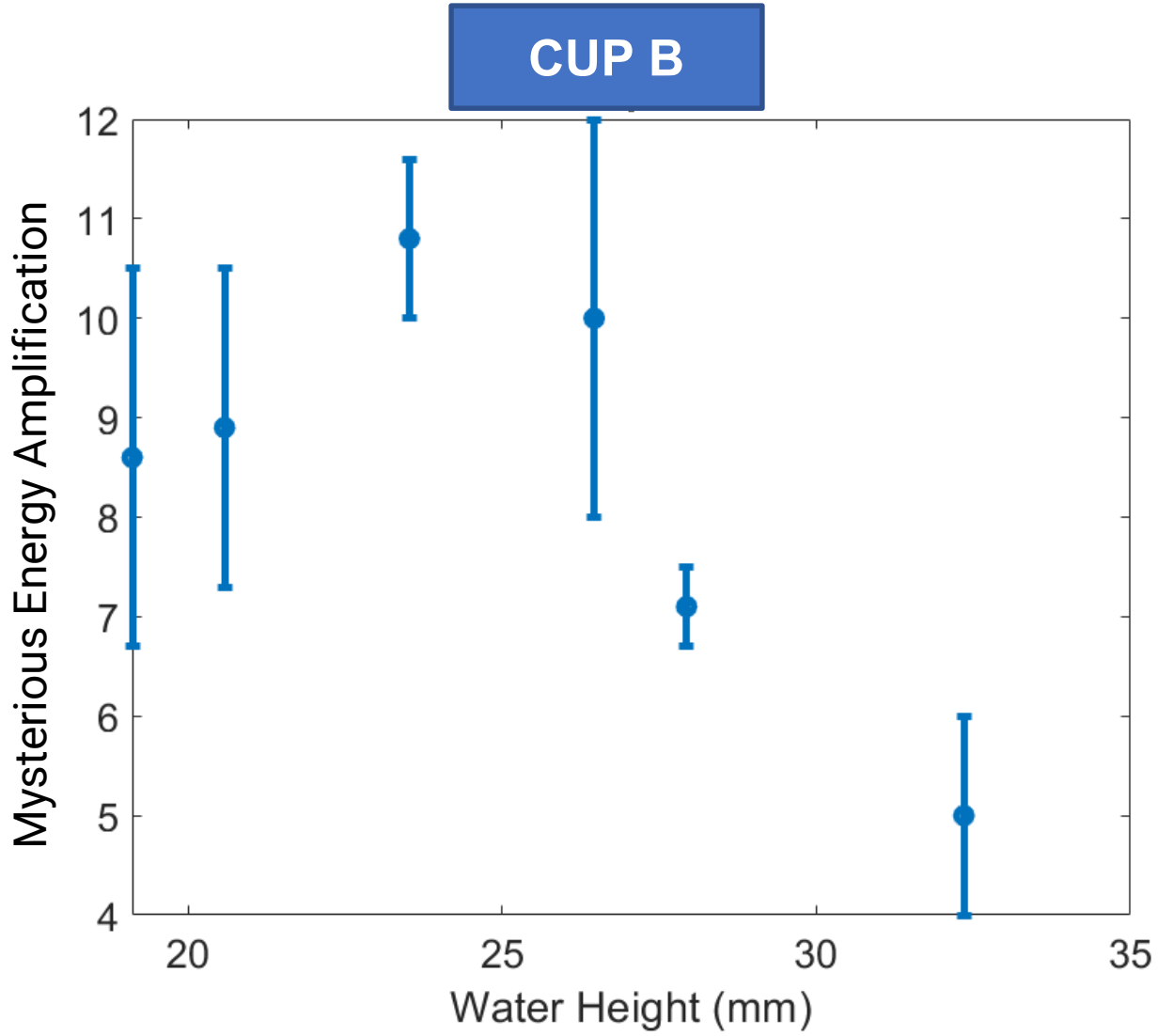
Maximal Fraction of Energy Transfer

13(3) % at **13.2mm** of water

Maximum Height

2.3(3)m at **32.3mm** of water

Chapter 2- Results: Finding trends for cup B



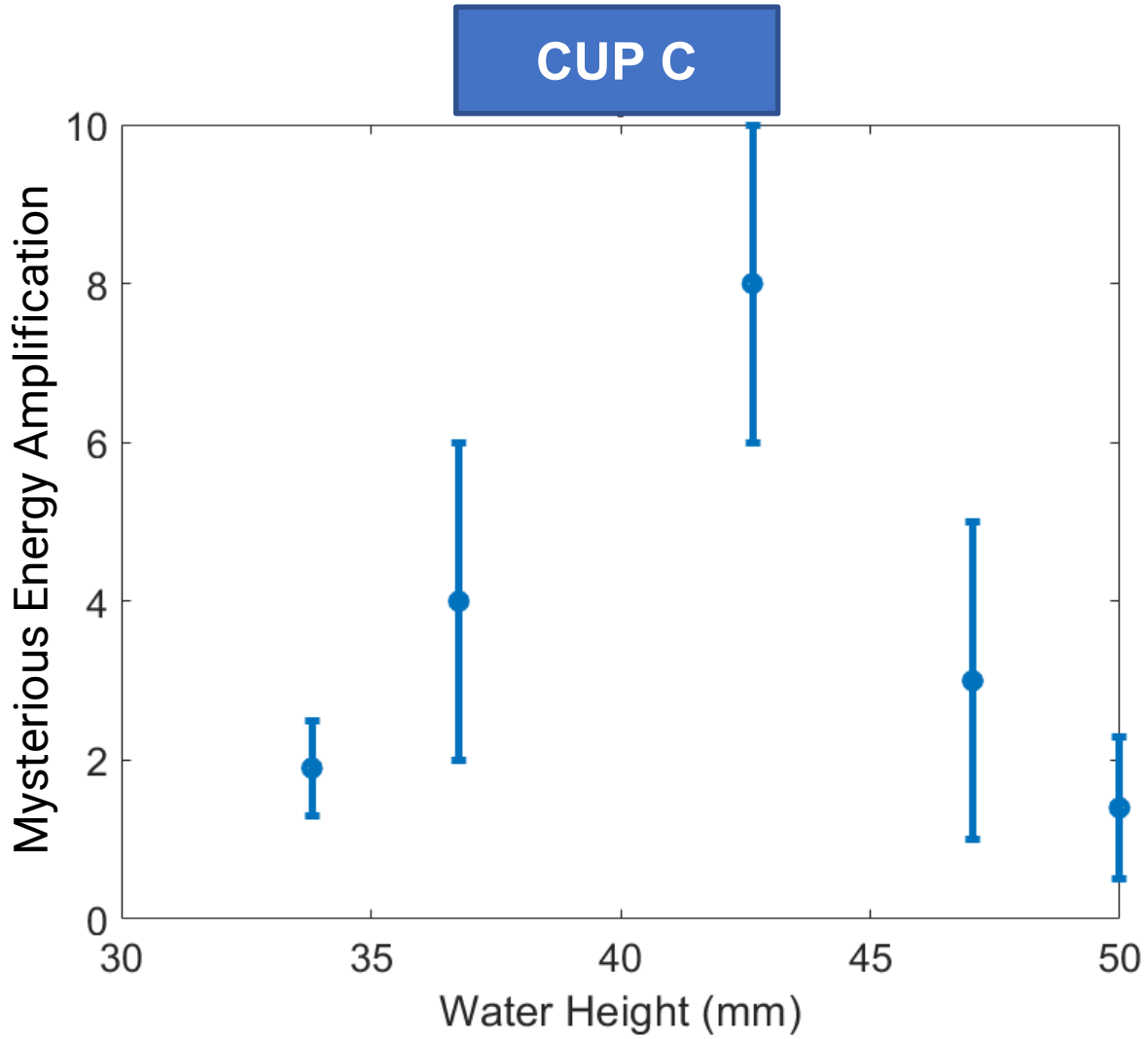
Maximal Fraction of Energy Transfer

10.8(8) % at **23.5mm** of water

Maximum Height

2.7(1)m at **23.5mm** of water

Chapter 2- Results: Finding trends for cup C



Maximal Fraction of Energy Transfer

8(2) % at **42.6mm** of water

Maximum Height

2.5(5)m at **42.6mm** of water

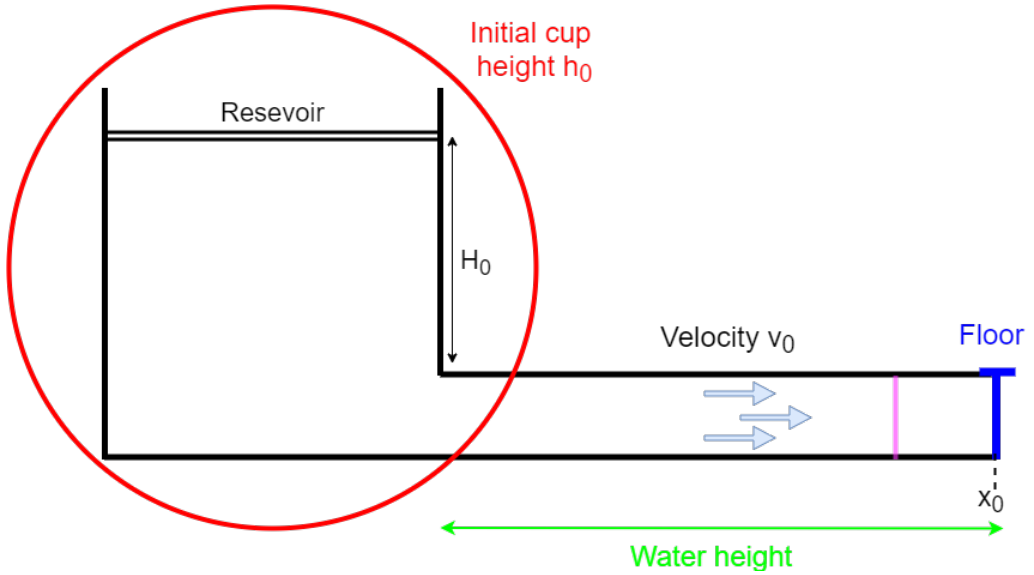
Chapter 2- Results: Conclusion

Maximal fraction of energy amplification was given by cup A: **13%** at **13.22mm** of water

Maximum height given by cup A: **2.7m** at **23.5mm** of water

Cups with smaller diameters are more efficient at amplifying energy.

Chapter 3- How we understood it: An analogy



Analogy to a similar known problem
The Water Hammer Effect

Ram pump + incompressibility

Conservation of mass and momentum

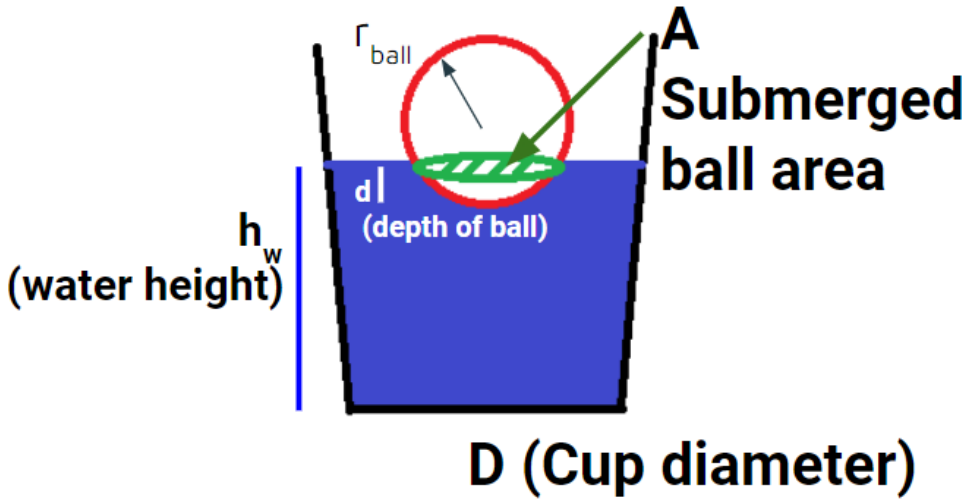
Neglect dissipation of shear forces.

Low mach number approximation.

Joukowsky Equation

$$\Delta P = \pm \rho a \Delta V$$

Chapter 3- How we understood it: Modeling the force



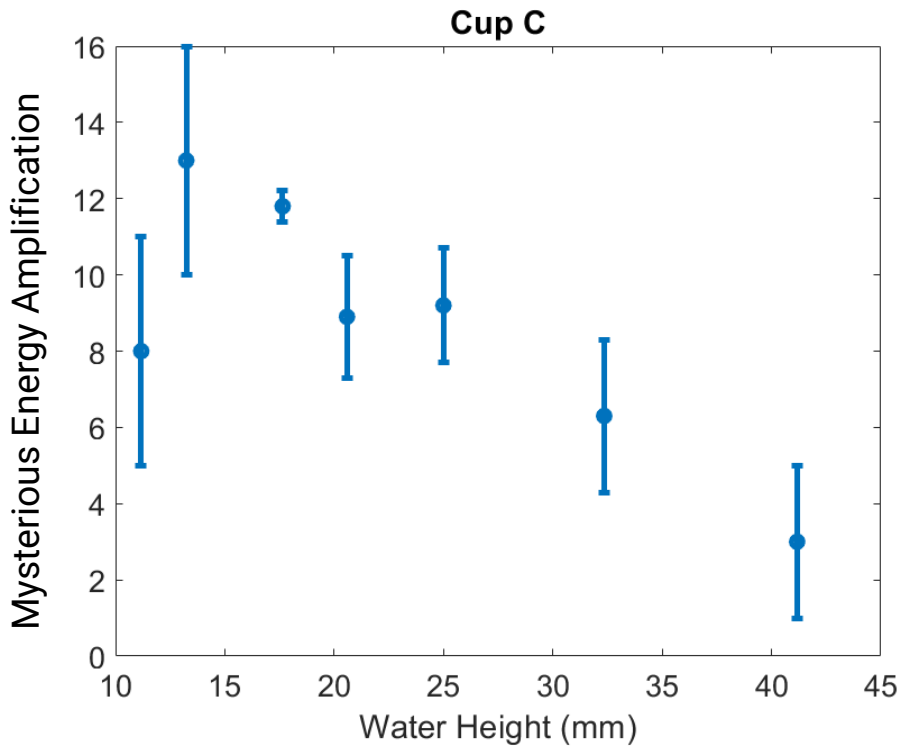
$$W = \pi \rho a \sqrt{2gh_0} d^2 [\frac{D_{ball}}{2} - \frac{d}{3}]$$

The work done by the water on the ball can be found by integrating the force acting on the ball

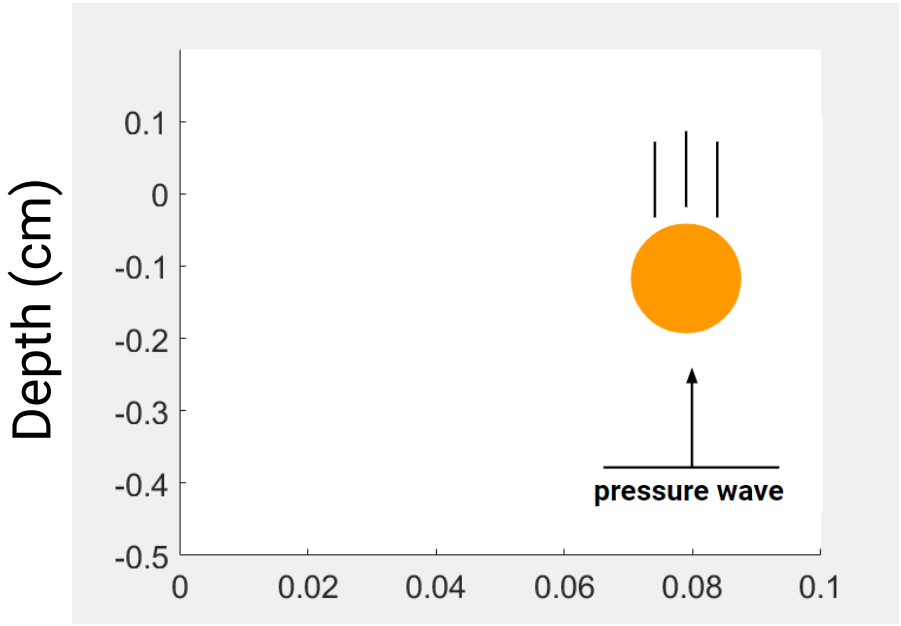
$$E_{transfer} = \frac{W}{E_{total}} = \frac{\pi \rho a \sqrt{2} d^2}{\sqrt{gh_0}(\frac{\rho \pi D_{cup}^2 h_w}{4}) + m_{ball}} [\frac{D_{ball}}{2} - \frac{d}{3}]$$

Energy amplification heavily depends on the depth reached by the ball and is inversely proportional to the height of water in the cup.

Chapter 3- How we understood it: Looks good, but we cannot measure depth!



$\frac{1}{h_w}$ Trend looks good



Position of pressure wave (cm)

Depth is estimated numerically through a system of differential equations.

Chapter 4 – Initial Conclusions

We also built an experimen**ptimize the energy transfer** given a set of cups and bal

We **proposed to explain the**m the water to the ball.

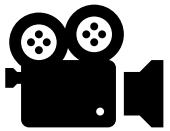
Within experimental precis**t predict a maximum**. **accurately predicts lower e** **amplification** for higher wa

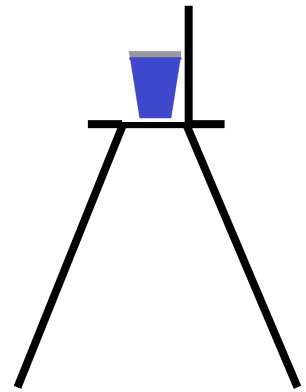
Chapter 5 – A Closer Look.

Phantom v7.3

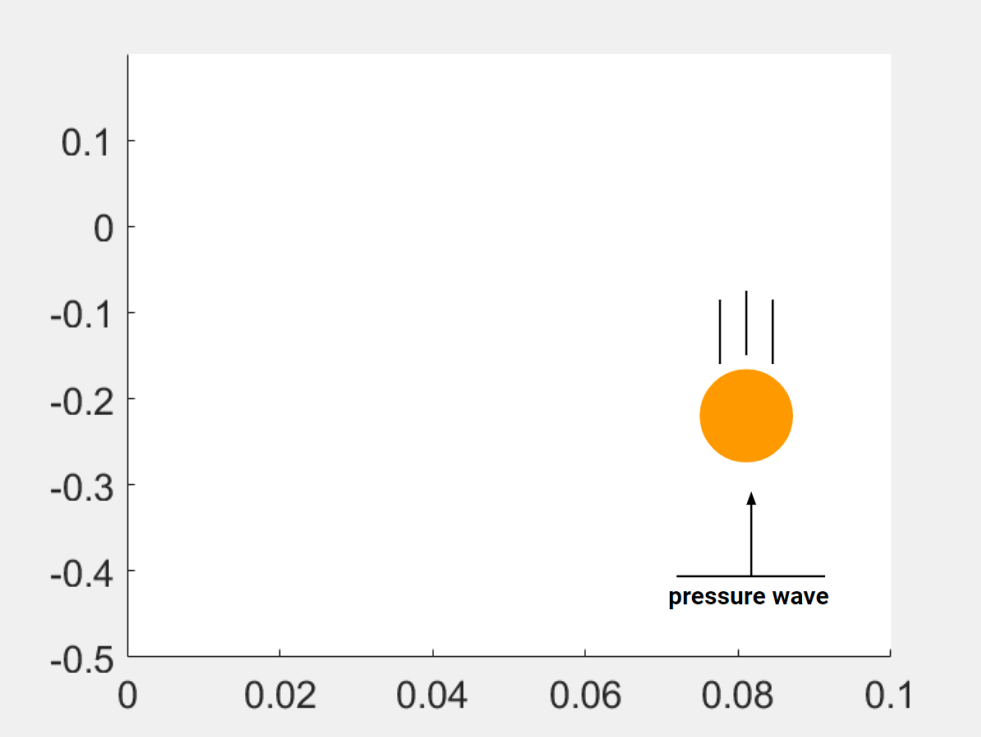
800 x 600 at 6,688 frames-per-second, and up to 500,000 fps with the new Turbo Mode.

Goal: Understand what is happening during the collision



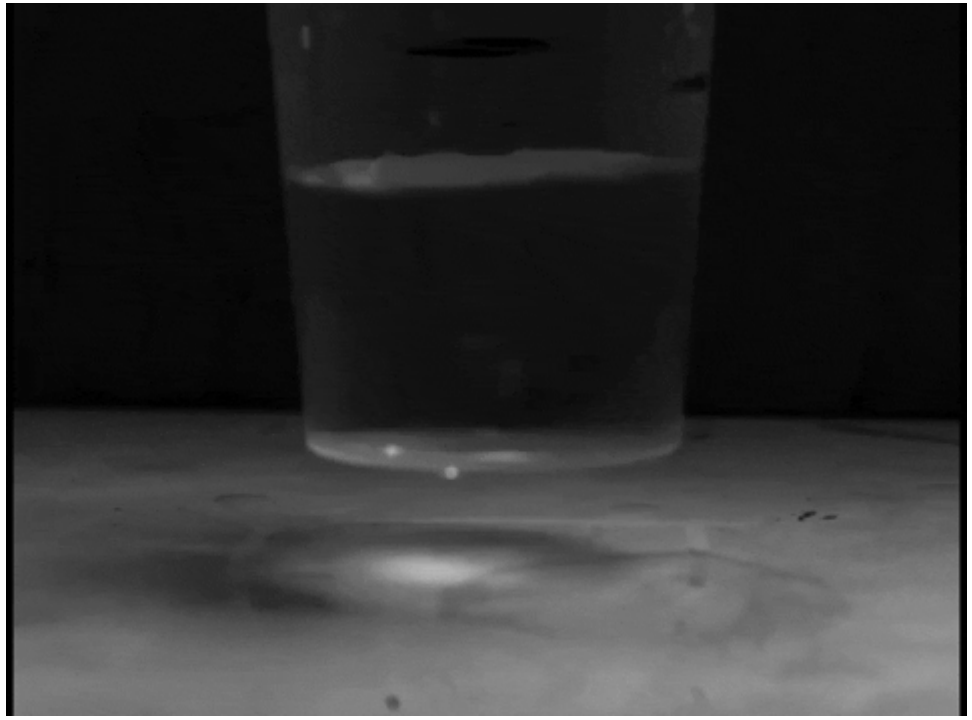


Chapter 5 – A Closer Look: what we got wrong part 1.

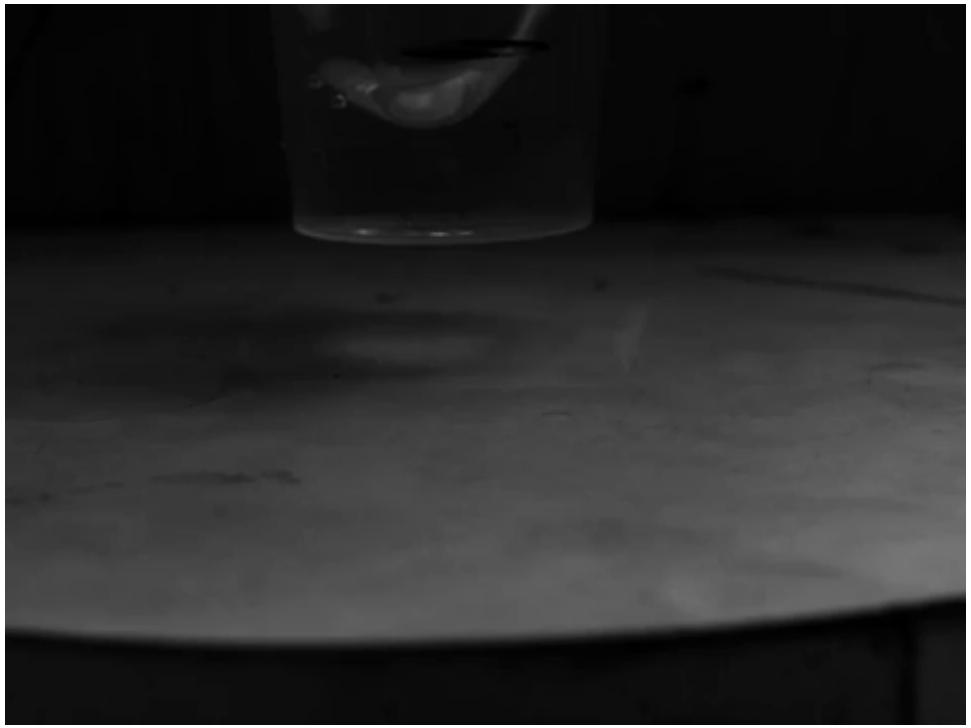


There is no “meeting of waves”, the ball sinks during the fall and starts going up as soon as it hits the ground.

Chapter 5 – A Closer Look: what we got wrong part 2.



NO Swirl



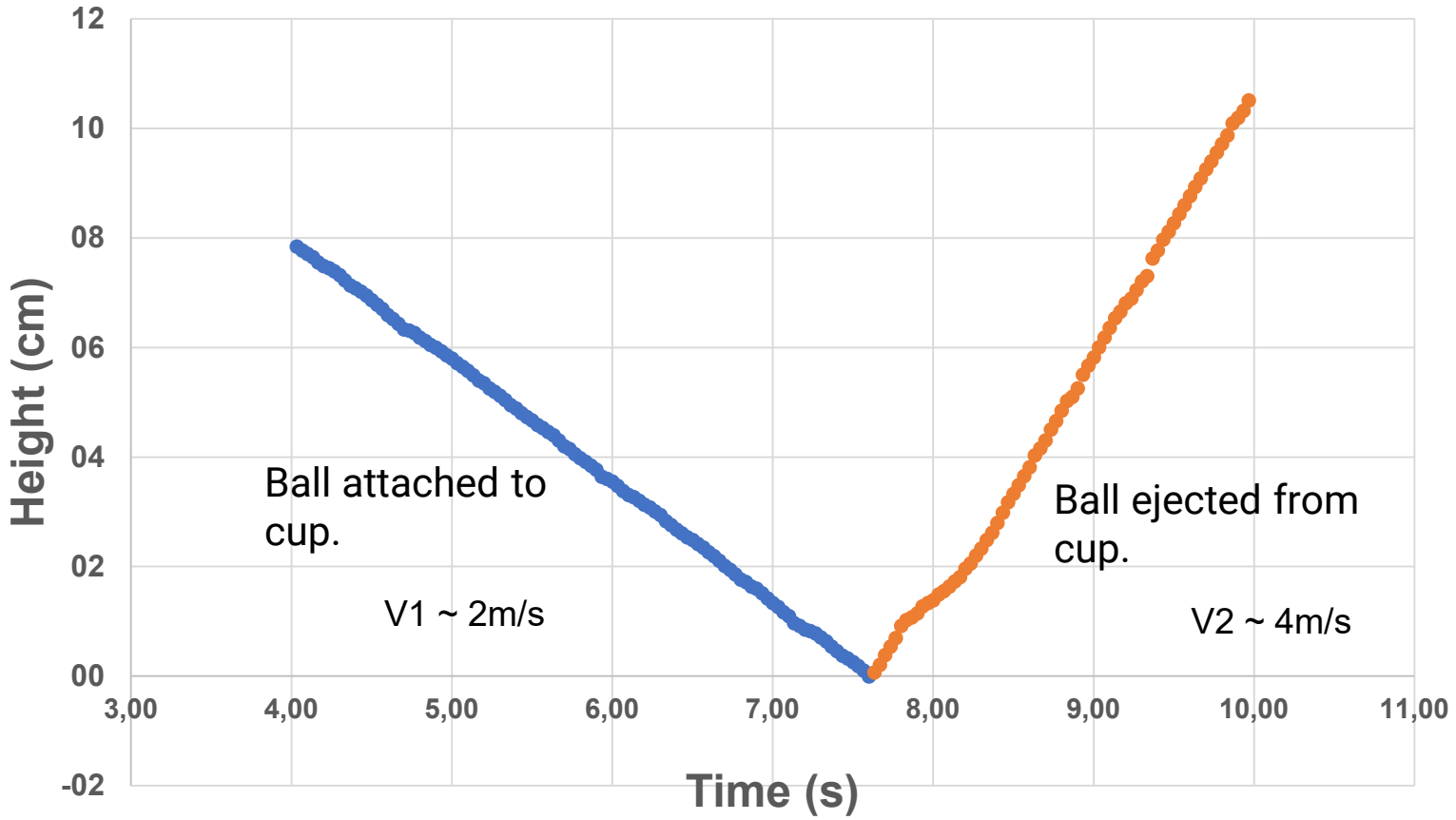
Swirl

The “gentle swirl” might have a bigger impact than earlier assumed.

Definitely check out Team Russia’s presentation in the final!

Chapter 6 (IV) – A New Hope:

High framerate video allows for measurements of actual **kinetic energy before and after the collision**.

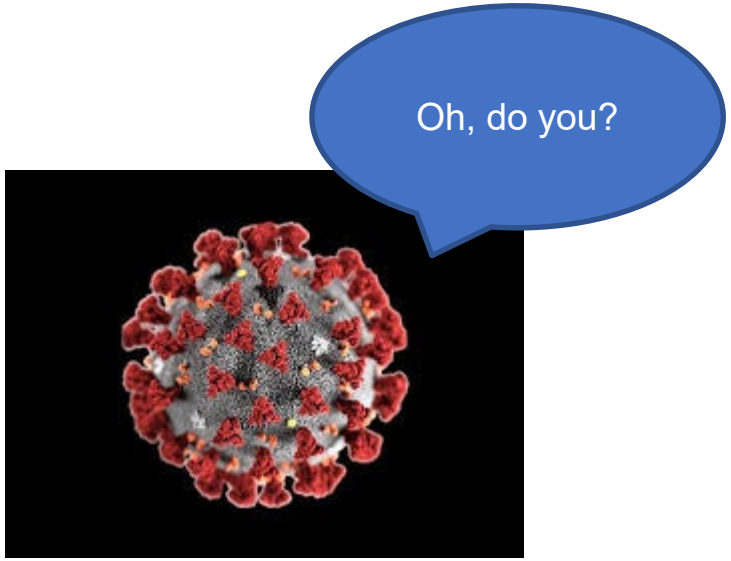


Chapter 6 (IV) – A New Hope:

High framerate video allows for measurements of actual **kinectic energy before and after the collision**.

Also...

- Depth;
- Ball collisions with the sides;
- How “flat” was the fall;
- ...



With new found evidence, we should step back to experimentation...

Chapter 7 - Today

We are eager to see the solutions to problem #01 presented both at the conference and at the competition!

We think our data can help understand exactly what is happening during the collision, and we are making our data OPEN so we can collaborate with everyone.

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Thank You!