ICYS

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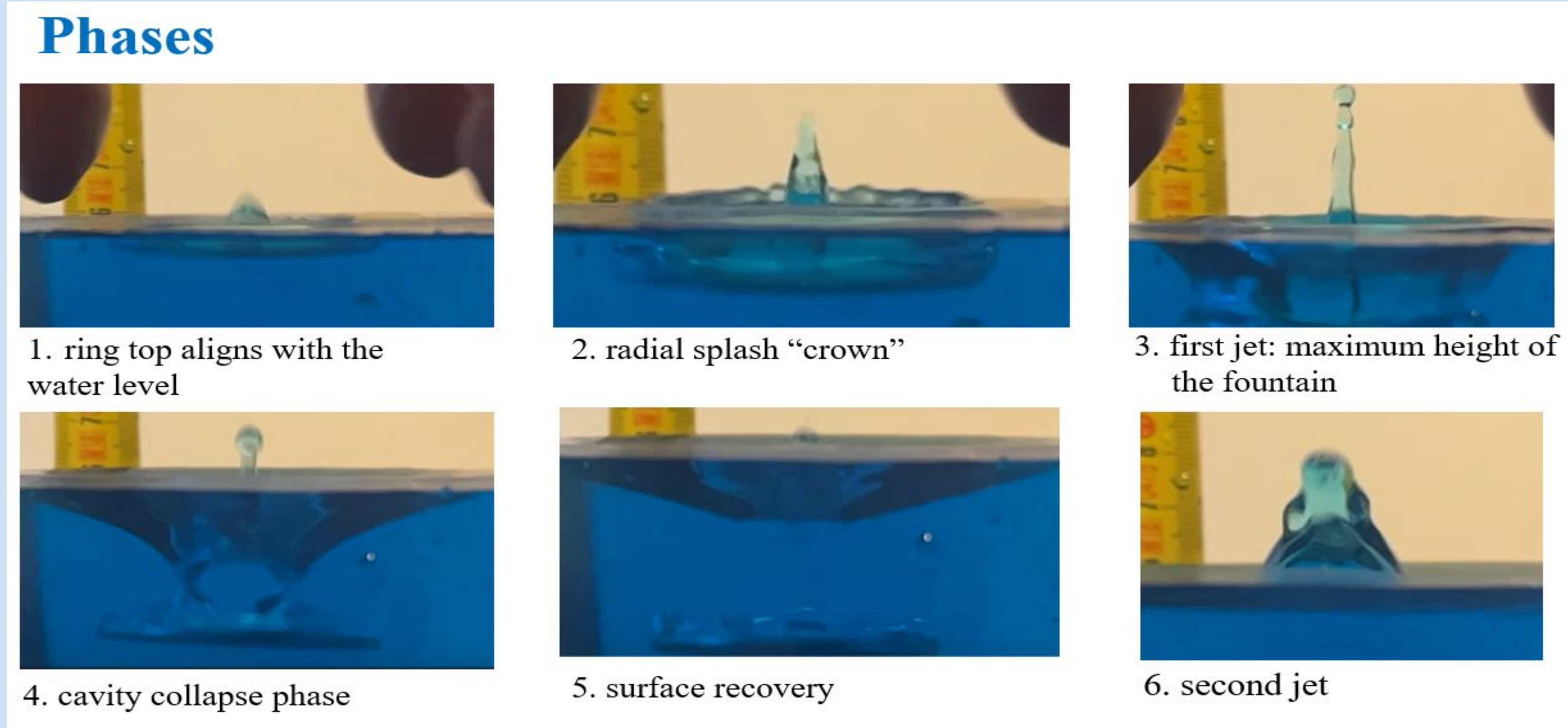
Ring Fountain Dynamics:
New approaches for low-energy mixing systems

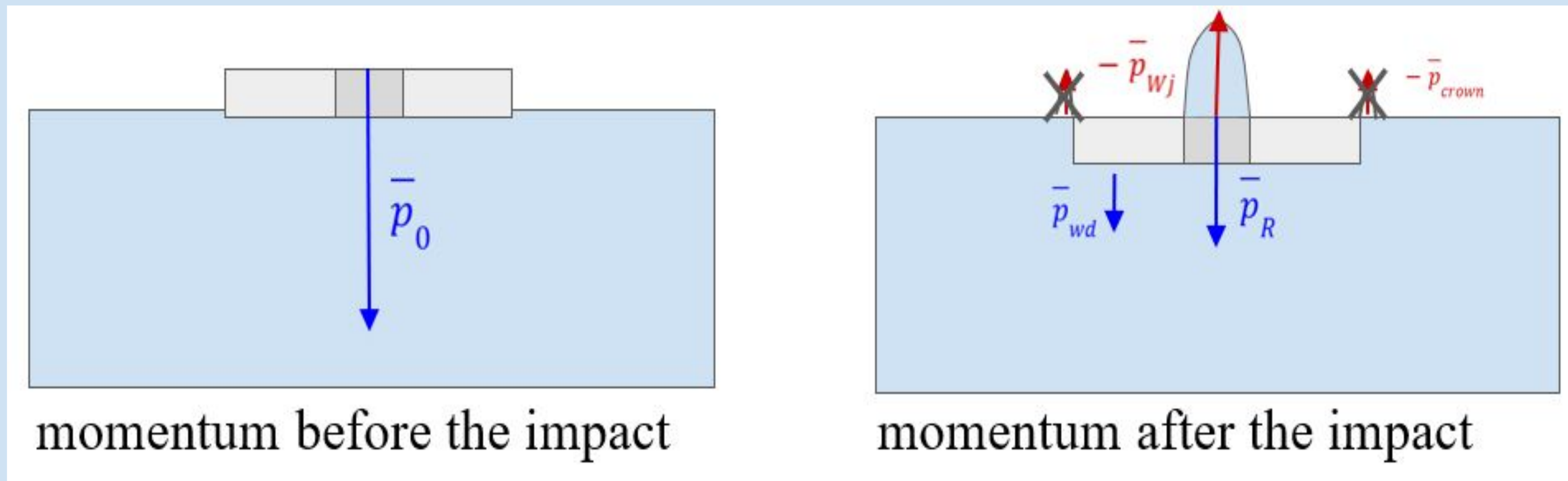
Abstract:

In my project, I am investigating the dynamics that occur when flat rings of matter fall into water, creating a jet phenomenon. I am analyzing how different parameters influence the maximum height of this jet. The higher the jets are, the more efficient the mixing of the liquids, which in turn is of great importance for the future and for energy savings. In doing so, I consider both the physical fundamentals and the practical implications.

Research questions:

- **How does the water jet form when a flat ring is immersed in the liquid?**
- **Which parameters (e.g., geometry, velocity, immersion depth) influence the maximum height of the jet?**
- **Which physical principles govern the dynamics of the jet phenomenon?**





Theory:

Approximately closed system over the time interval Δt →

Application of the principle of momentum conservation:

$$\bar{p}_0 = \bar{p}_{wu} + \bar{p}_R + \bar{p}_{Wj} + \cancel{\bar{p}_{Krone}}$$

$$m_R \cdot v_{R0} = m_{wu} \cdot v_R + m_R \cdot v_R - m_{wj} \cdot v_{wj}$$

$$m_R \cdot (v_R - v_{R0}) = m_{wu} \cdot v_R - m_{wj} \cdot v_{wj}$$

Determining the velocity of the water jet:

$$\Delta p = \rho \cdot \Delta t \cdot A_R \cdot v_R^2 - \rho \cdot \Delta t \cdot A_{wj} \cdot v_{wj}^2$$

$$v_{wj} = \sqrt{\frac{\rho \cdot v_R^2 \cdot \Delta t \cdot A_R - m_R (v_R - v_{R0})}{\rho \cdot \Delta t \cdot A_{wj}}}$$

Determining the ring's velocity after impact:

$$v_R = \frac{-m_R \pm \sqrt{m_R^2 + 4 \cdot \rho \cdot \Delta t \cdot (m_R \cdot v_{R0} + m_R \cdot g \cdot \Delta t) \cdot A_R}}{2 \cdot \rho \cdot \Delta t \cdot A_R}$$

Theory regarding the speed of the water jet:

$$v_{wj} = \sqrt{\frac{\rho \cdot \left(\frac{-m_R \pm \sqrt{m_R^2 + 4 \cdot \rho \cdot \Delta t \cdot (m_R \cdot v_{R0} + m_R \cdot g \cdot \Delta t) \cdot A_R}}{2 \cdot \rho \cdot \Delta t \cdot A_R}\right)^2 \cdot \Delta t \cdot A_R - m_R\left(\left(\frac{-m_R \pm \sqrt{m_R^2 + 4 \cdot \rho \cdot \Delta t \cdot (m_R \cdot v_{R0} + m_R \cdot g \cdot \Delta t) \cdot A_R}}{2 \cdot \rho \cdot \Delta t \cdot A_R}\right) - v_{R0}\right)}{\rho \cdot \Delta t \cdot A_{wh}}}$$

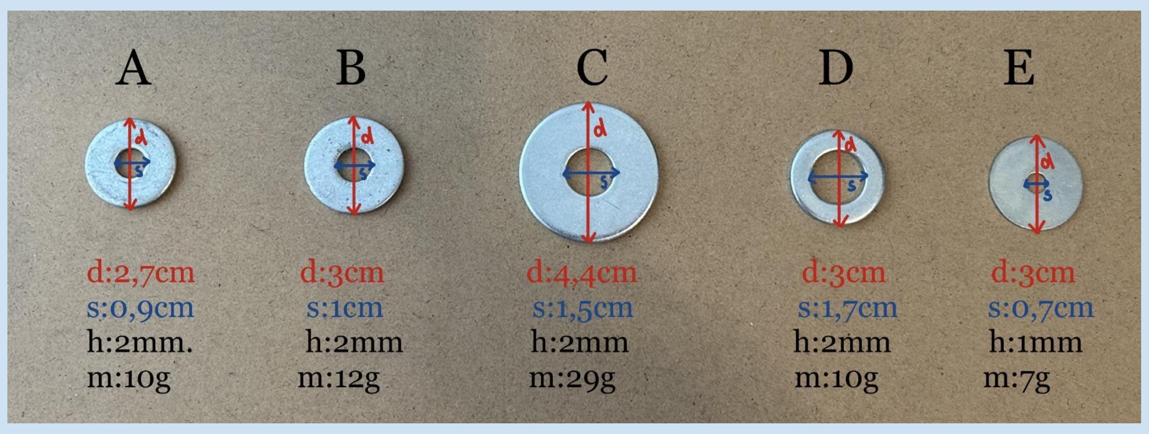
Experiments:

Falling methods:

- Short falling heights: manual release of the rings
- Long falling heights: improved setup with metal strips for stabilization
- Objective: to ensure the impact is as parallel as possible

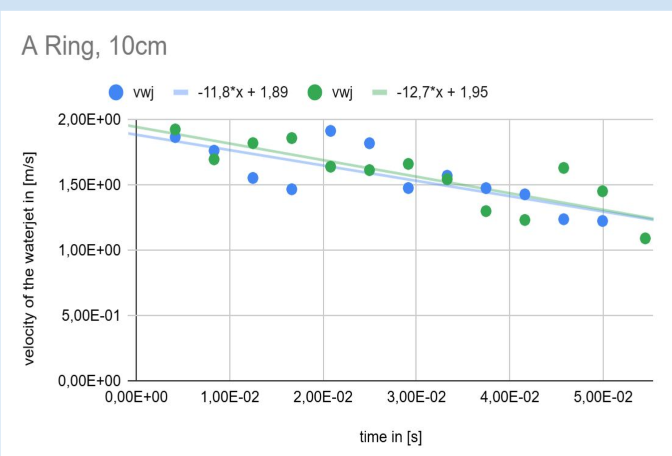
Materials:

- Flat metal rings (washers) with varying dimensions
- Transparent plastic containers with the same radius, filled to the brim with colored water (to prevent surface currents)
- Experiments analised in Tracker (240fps)

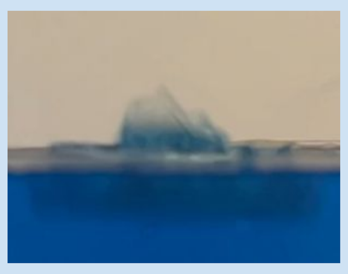


Experiments and results:

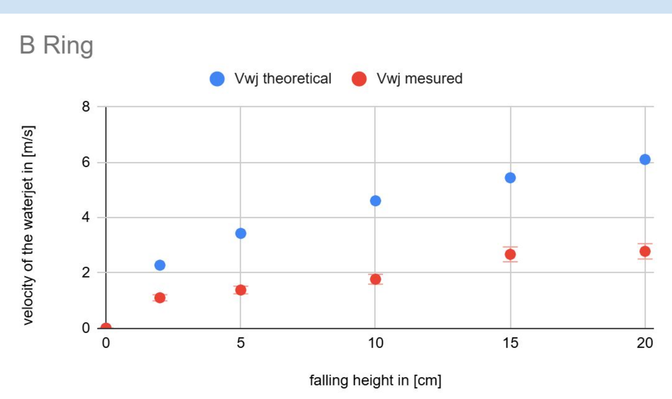
Different falling heights (1-20cm):

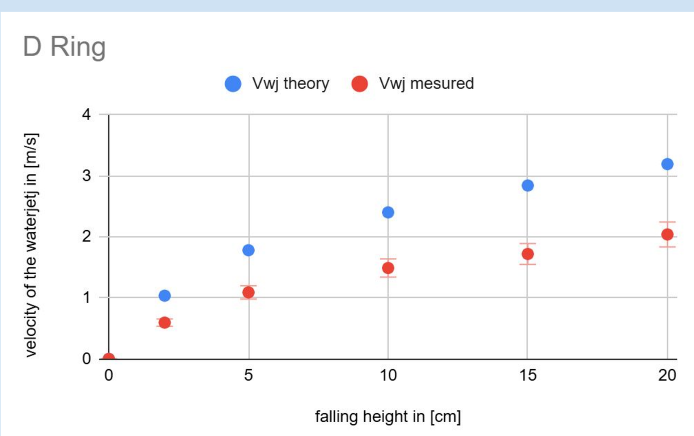


B Ring: big crown

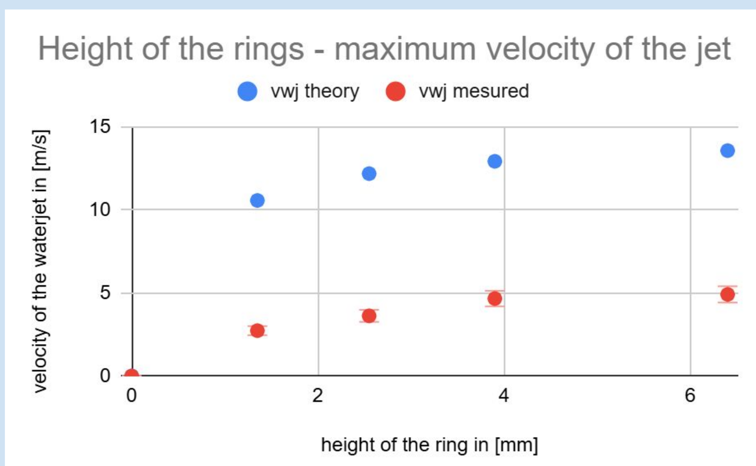


D Ring: small crown

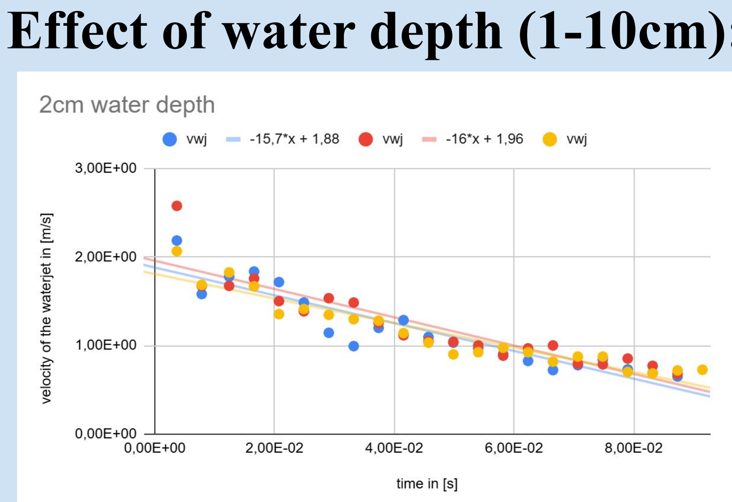


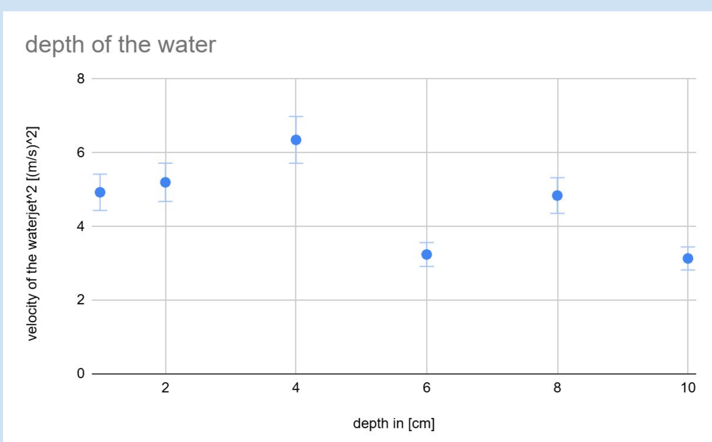


Height of the ring:

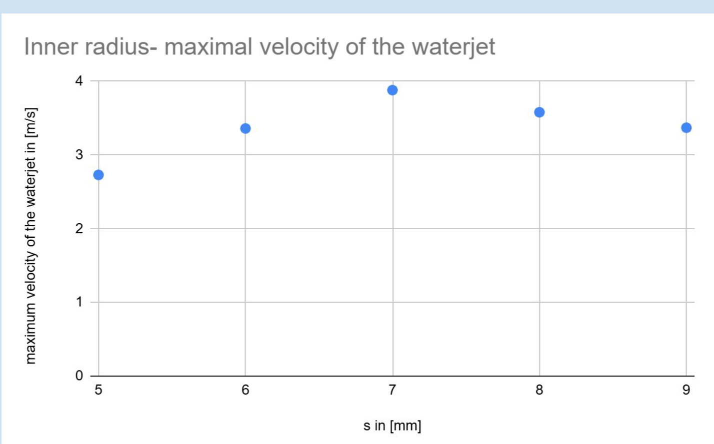


Effect of water depth (1-10cm):





Different inner diameters (5-9mm):



- Neglecting the "crown" → Discrepancy between experiment and theory
- For rings with a small inner diameter, the pointed crown becomes larger because the displaced water has to flow out to the sides → greater deviation

Conclusion:

- **As the diameter of the ring's hole decreases (up to an optimum), the maximum height of the water jet increases**
- **As the height (and the mass) of the ring increases (up to an optimum), the maximum height of the water jet also increases**

- **Crown tracking → greater measurement accuracy**
- **Parallel impact is difficult to achieve**
- **Higher frame rate → more accurate results**

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