solution to the problem no. 2
presented by the team of Austria.

Popping body
A body is submerged in water. After release it will pop out of the water.
How does the height of the pop above the water surface depend on the initial conditions (depth
and other parameters)?

Abstract
As the initial conditions we considered mass, volume, depth and the shape and surface of the
ball. The main forces in our first approach were gravity, buoyancy and flow resistance. After
measuring we found out that this approach is only valid in shallow depth. We observed the
decrease of maximum height with increasing depth. So we assumed that the reaching of the
water surface should be a critical moment. Before reaching the surface the body reaches its
maximum speed. When it goes through the surface, the buoyancy decreases, and the lower
pressure at the bottom of the body has a negative impact on th velocity. This led us to our
second approach: “Potentional flow”. We ignored friction, turbulences etc. and considered
the energy which is needed to accelerate water masses. This we called “virtual mass”. To
achive a solution we created a numerical algorithm, which corresponded more or less to our
observations.

Overview
- Initial conditions
- Forces
- First approach
- Expected heights versus measured heights
- Second approach: Potential flow
- Algorithm
- Problems
- Experiments
2: Popping body

1 Initial conditions

- Mass $m$
- Volume $V$
- Depth
- Shape, surface

2 Forces

- Gravity $mg$
- Buoyancy $\rho gV$
- Flow resistance

3 First approach

$$ma = \rho gV - gm - \frac{1}{2}c_W A v^2$$

4 Expected heights versus measured heights

![Graph showing expected versus measured heights](image)

Figure 1: Expected heights versus measured heights

5 Second approach: Potential flow

- Ignoring friction, turbulences etc.
- Energy is needed to accelerate water masses ("virtual mass" $mv$).
- Simplifications when reaching the surface.
- Numerical solution.
6 Algorithm

Loop:

\[ t := t + dt \]
\[ a := \frac{F}{m + mv} \quad \text{inside water} \]
\[ v := v + a \, dt \]
\[ h := h + v \, dt \]

Popping ball \((r = 10 \text{ cm})\) in shallow depth

![Graph](image)

Figure 2: Shallow depth

7 Problems

- Only valid in shallow depth.
- Cannot explain the **decreasing** maximum height

  \textit{Critical moment} = reaching the surface

- Development of whirls takes some time.
- Body reaches a maximum speed.
- Buoyancy decreases when reaching the surface.
- Lower pressure at the bottom of the body has a negative impact on the velocity.
8 Experiments

Figure 3: Experiments