Team Second 2026

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1 Introduction

For Team Second, my team and I wanted to record a fluid "solving" a maze. We had seen similar videos where a clear maze had been created with air tight seals, and water had gone through, solving the maze, due to the built up air pressure in dead ends pushing the water out. It turns out that creating these mazes was a much more complicated task than what we expected which lead to this video not being up to the quality I was hoping. However, it provided some interesting fluid behavior and demonstrated areas to improve for our final team third.

2 Fluid Behavior

At a very simple level, the water can't really solve the maze. Below, Figure 1, is a depiction of the maze which will be referenced to assist in analysis of the flow behavior.

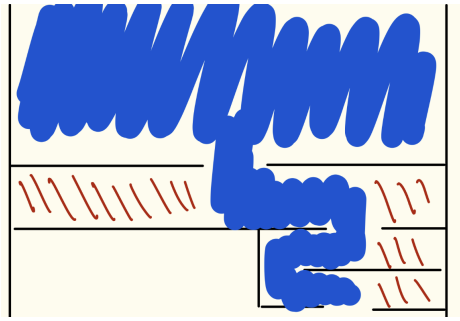


Figure 1: Schematic of maze

As the water, blue, initially pours into the maze, it forms a seal over the entrance, trapping any air, red, in the maze. As it begins to flow throughout the cavity, it pushes air either out of the maze, or further traps it in the dead ends. In those dead ends, the air pressure builds and builds until its higher than the pressure of the water, forcing it the other direction. In the case where the air is able to escape, the water pressure is consistently higher than the air pressure meaning it is able to exit as well.

We can quantify the behavior of this flow further by using the Euler number which is defined as

$$Eu = \frac{\Delta P}{\rho v^2}$$

where ΔP is the change in pressure, ρ the density of the fluid, and v the velocity of the fluid. If we use air as our fluid, we will assume that the initial pressure of the air is 0Pa. This is because we will define our reference pressure

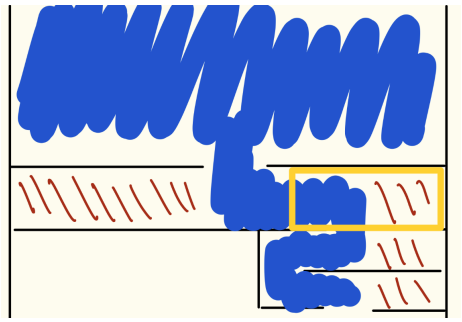


Figure 2: Schematic of maze with area of interest surrounded by yellow box

being where the air initially exists in the maze. The final pressure is equivalent to the pressure of the water at that reference line. Since the pressure is defined by

$$P = \rho g h$$

the pressure of the fluid is changing throughout the maze. As the water flows through, the pressure is also changing. We will analyze a position earlier in the maze for ease of calculation. Seen below is again the image of the schematic, but now with a yellow box around the area that will be looked at.

Here, there is an additional 8 inches of water at the start of the flow. Such, the pressure of water when the air is compacted is most nearly

$$P_{water} = 1993.392Pa$$

We will also need to determine the velocity of the air. We will again assume that the air is moving at the same rate the water is moving. We will use the equation

$$v = \sqrt{2gh}$$

to determine what the velocity of the air is. Again since the velocity is changing as the water flows through the maze, we will assume our height to be from where the water was poured from, which was 12 inches from the top of the maze entrance. Thus we find

$$v = 2.45m/s$$

Combining all this with the known density of air $\rho = 1.225kg/m^3$ we find that

$$Eu = 2.5$$

which indicates a heavy friction and obstructions in the flow which is expected as the air is getting squished rapidly into the wall.

We can also characterize the flow as Viscous fingering, "Viscous fingering is the unilateral displacement of a highly mobile fluid upon interacting with a sluggish native fluid" [2]. Notably these effects are most present when the air pressure builds up and begins to push back against the much more viscous water. This causes some "finger" like shapes to occur near the ridges of the maze where the air and water are colliding with each other.

One other aspect that is left behind after the flow is over, is pinning from capillary action, "Low pinning of the contact line reduces the energy required to move a droplet" [1]. Notably, the opposite is what occurs here. Due to the geometry in the corners of the maze, the water is interfaced with a high surface area and a coarse surface which causes a fair amount of liquid to remain in the crevices.

3 Visualization Technique

For the visualization technique, I wanted the maze itself to serve as a way to see the flow. I was hoping that the overhead light from my kitchen and the brown background of the acrylic would provide enough contrast between the fluid the acrylic itself, but it did not. I should have added some color to the water in order to make it more visually distinct and stand out from the background and avoid being washed out from the lights.

4 Photographic Technique

To image this flow I used a Canon Rebel 70D with a 50mm EF lens. The video was originally recorded in 1080p 30fps from around 4 feet away. I wanted to capture the full maze which is why I had the camera so far away. Noticably, this led to a loss of overall image quality in favor of seeing the full stream.

When I recorded the original, there was still a fair amount of excess space. I should have cropped the video some more in order to make the flow a further focus. Not having cropped the video lead to a poor spatial resolution. Since this video was recorded in 30fps and the flow is not moving very fast, the temporal resolution is fine. Had I recorded it in a higher fps, then I would have been able to capture more nuances of the flow.

5 Image Assessment

I am generally pleased with how this turned out given how much I was willing to spend on this. In all, this setup cost me $50. If I were to spend more, I would like to capture it in a more artistic manner. Having a solid neutral background and even lighting, or perhaps glow-in-the-dark fluid would be very nice. Focusing on the image more will be a major focus for me in Team Third.

I'm torn on if the choice to use the Canon 70D was worth it over filming on my iPhone 13. While I like getting the exposure to using the camera, I also know that the iPhone's ability to capture video is much better. Doing another video, I would like to explore what major differences are in video for the iPhone and Canon versions.

The last thing that would make this video much better would be having a better designed maze. As mentioned, this was expensive so I could only afford one attempt. The main issues that didn't allow this to work as well as I had hoped were a small opening, causing a smaller mass flow causing air to escape before it can properly "direct" the maze and that there were leaks between panels.

References

[1] Bethany V. Orme et al. “Droplet Retention and Shedding on Slippery Substrates”. In: *Langmuir* 35.28 (June 2019), pp. 9146–9151. DOI: 10.1021/acs.langmuir.9b00931.

[2] Richard L. Wallace et al. “Utility-Scale Subsurface Hydrogen Storage: UK Perspectives and Technology”. In: *International Journal of Hydrogen Energy* 46.49 (July 2021), pp. 25137–25159. DOI: 10.1016/j.ijhydene.2021.05.034.