Objective

This summary is aimed to outline the flow process of determining the optimal discharge length that minimizes drain time of a simple fluidic system through engineering analysis of fluid mechanics. To begin analyzing the system overall there must first be assumptions outlined along with the given specifications for an accurate analysis of the system. To derive the physical representation of the system, fluid mechanic concepts such as flow regimes, steady state, mass flow rate, Bernoulli's equation and frictional losses had to be considered. After the conceptual analysis were understood, a mathematical model was created and tested in Matlab to allow for comparison of the model to the experimental data.

Assumptions

The assumptions made to begin analysis are the following:

1. The pipe material is assumed to be cast iron, with a roughness value of 0.0005 m for analysis.
2. The flow regime varies between laminar and turbulent, as indicated by the Reynolds number at different instants of the flow.
3. Due to the slow drain time, the system operates in a quasi-steady state, allowing the use of steady-state equations like the Bernoulli Equation at small instantaneous moments. At these specific points in time, the flow can be treated as having constant velocity and height.
4. The mass flow rate in the tube is not constant as the flow is draining. As the water level in the tank decreases, the pressure and velocity at the tube entrance decreases.
5. While the mass flow rate decreases over time as the water level in the tank drops—reducing pressure and velocity at the tube entrance—the quasi-steady assumption treats the mass flow rate as constant at each instant.
6. Losses in the system are dominated by frictional and minor losses, such as those caused by sudden contraction, while entrance, exit losses are negligible and excluded from the calculations.

Simple Fluidic System

The system outlined in the project incorporates fluid mechanic analysis utilizing primarily steady state analysis and Bernoulli's equation. As the flow is relatively slow, at instantaneous times the velocity and height of the fluid is constant which allows for steady state analysis of the system simplifying calculations. The flows behaviour transitioning from turbulent to transitional then laminar changes the frictional factor and consequently the velocity as well, as the velocity changes so too does the Reynold's number again. The Haaland equation was used to determine the frictional factor for turbulent flow, Darcy-Weisbach for laminar flow, and a weighted adjustment factor incorporating both for transitional flow (closer the Reynold number is to turbulent or laminar, the heavier each respective factor becomes). Head loss was calculated by incorporating the frictional and minor losses. Bernoulli is applied by relating the reservoir to the pipe, while also incorporating the head loss.

Optimal Design

The optimal design within this analysis is achieved when the distance the water can travel is the furthest while minimizing the time to drain, with the ideal tube length being 0.5 meters, which results in a drain time of 4 minutes and 35 seconds. As the travel distance and drainage time are equally important, they have been weighted the same allowing for an analysis through their ratio. A balanced one-to-one ratio indicates that the water travels a sufficient distance without causing excessively slow drainage, while also avoiding an overly short drainage time that would result in abrupt flow.

Work Division

All team members were present for discussions to determine the assumptions necessary to begin analysis and worked collaboratively in creating the script and presentation slides for the 10-minute video presentation. The derivation of the mathematical model was written by Kevin, the first iterations of code were created by Beverly and Adesh. The group as a collective troubleshooted the code which was finalized by Kevin. Lucy and Nathan helped with editing and presenting information in a clear method.