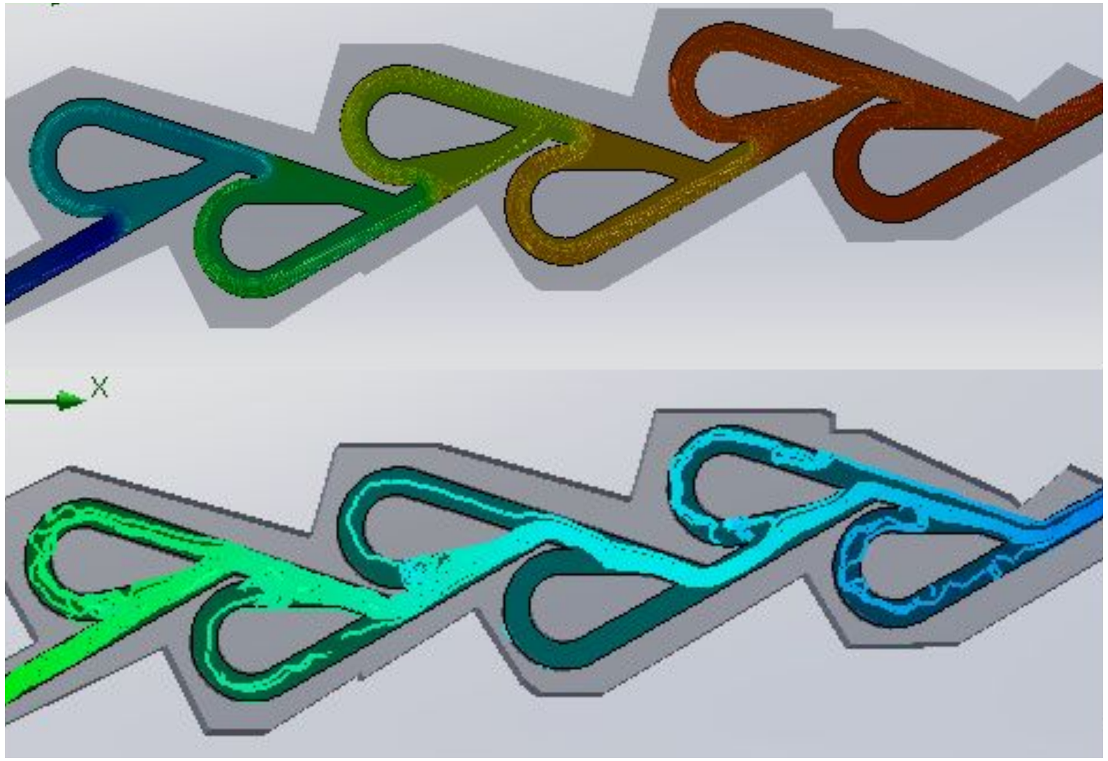
BRAZIL

IYPT 2018

Problem 10

Tesla Valve

Reporter: Victor Cortez



A Tesla valve is a fixed-geometry, passive, one-direction valve. A Tesla valve offers a resistance to flow that is much greater in one direction compared to the other. Create such a Tesla valve and investigate its relevant parameters.

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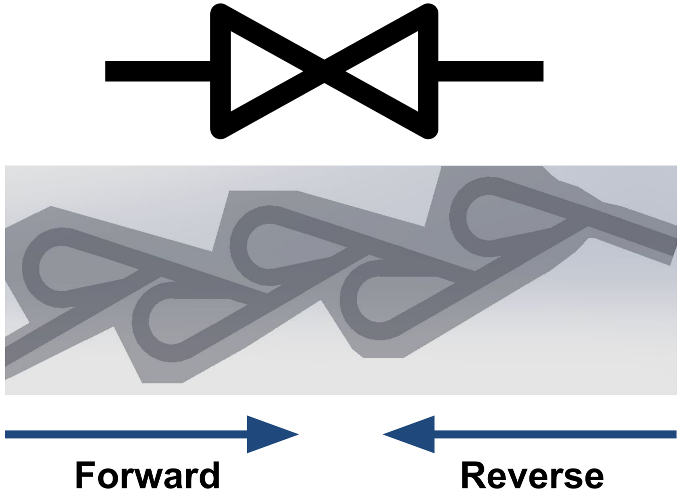
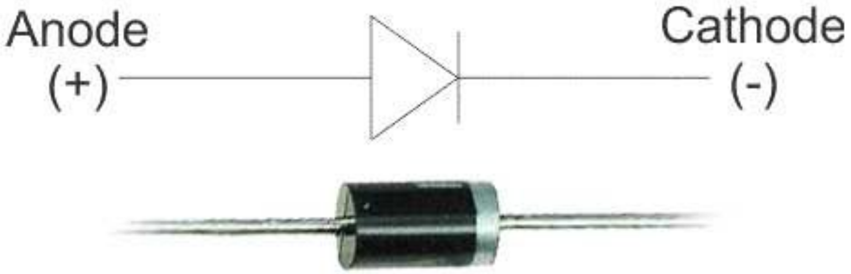
Introduction to the Valve





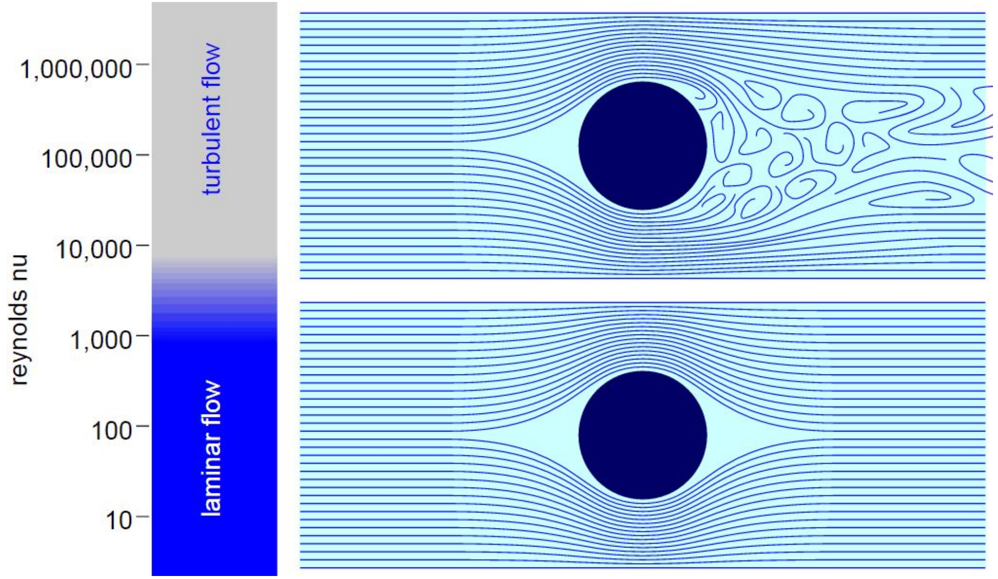
Diodicity

$$D = \frac{\Delta P_r}{\Delta P_f}$$

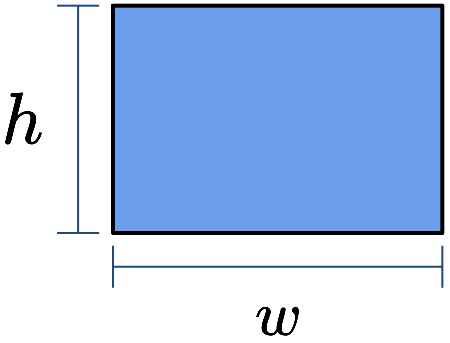
$\Delta P_r =$ **Pressure drop in the reverse direction**

$\Delta P_f =$ **Pressure drop in the forward direction**

Introduction to the Valve: Reynolds Number



$$Re_c \approx 2000$$



$$D = \frac{4A}{P} = \frac{2 \cdot h \cdot w}{h + w}$$

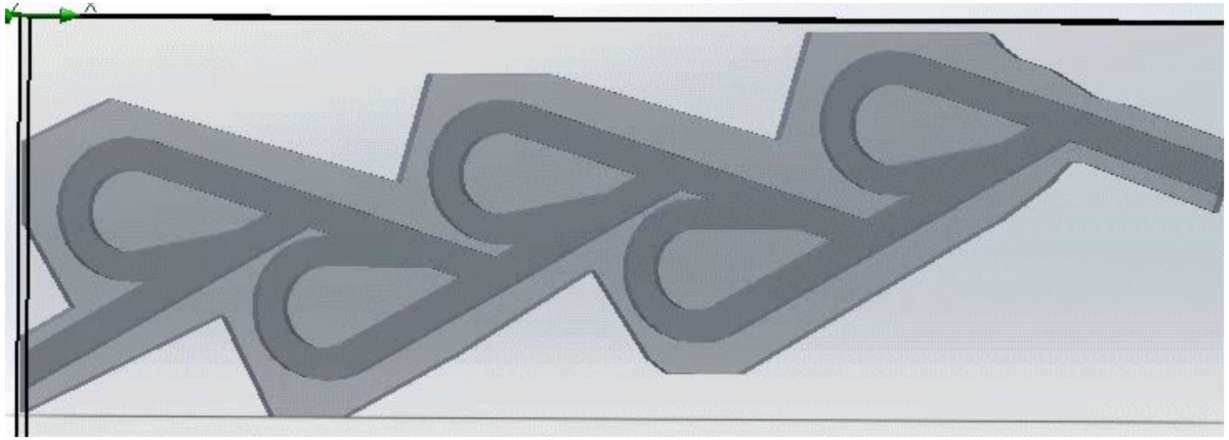
$$Re = \frac{\text{Inertia Forces}}{\text{Viscous Forces}} = \frac{\rho v D}{\mu}$$

$D =$ **Characteristic length**

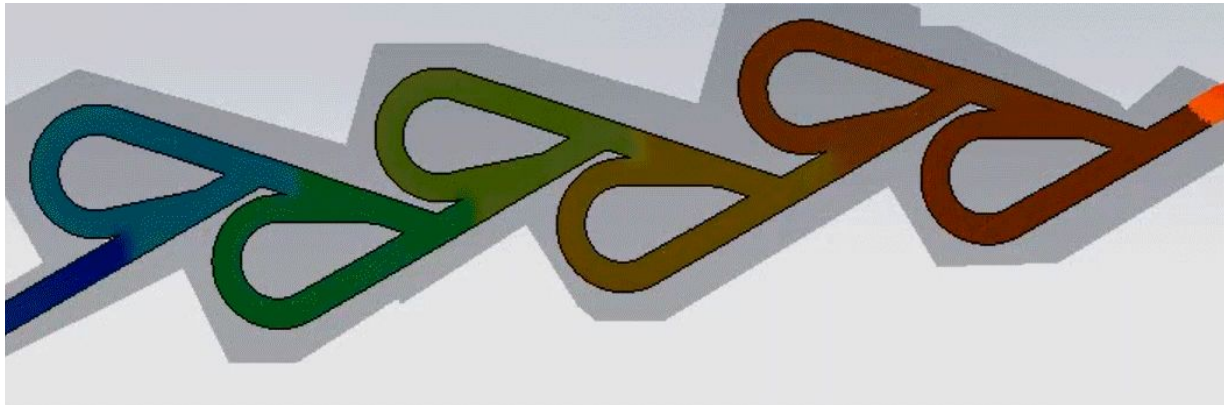
$v =$ **Flow velocity**

Qualitative Analysis

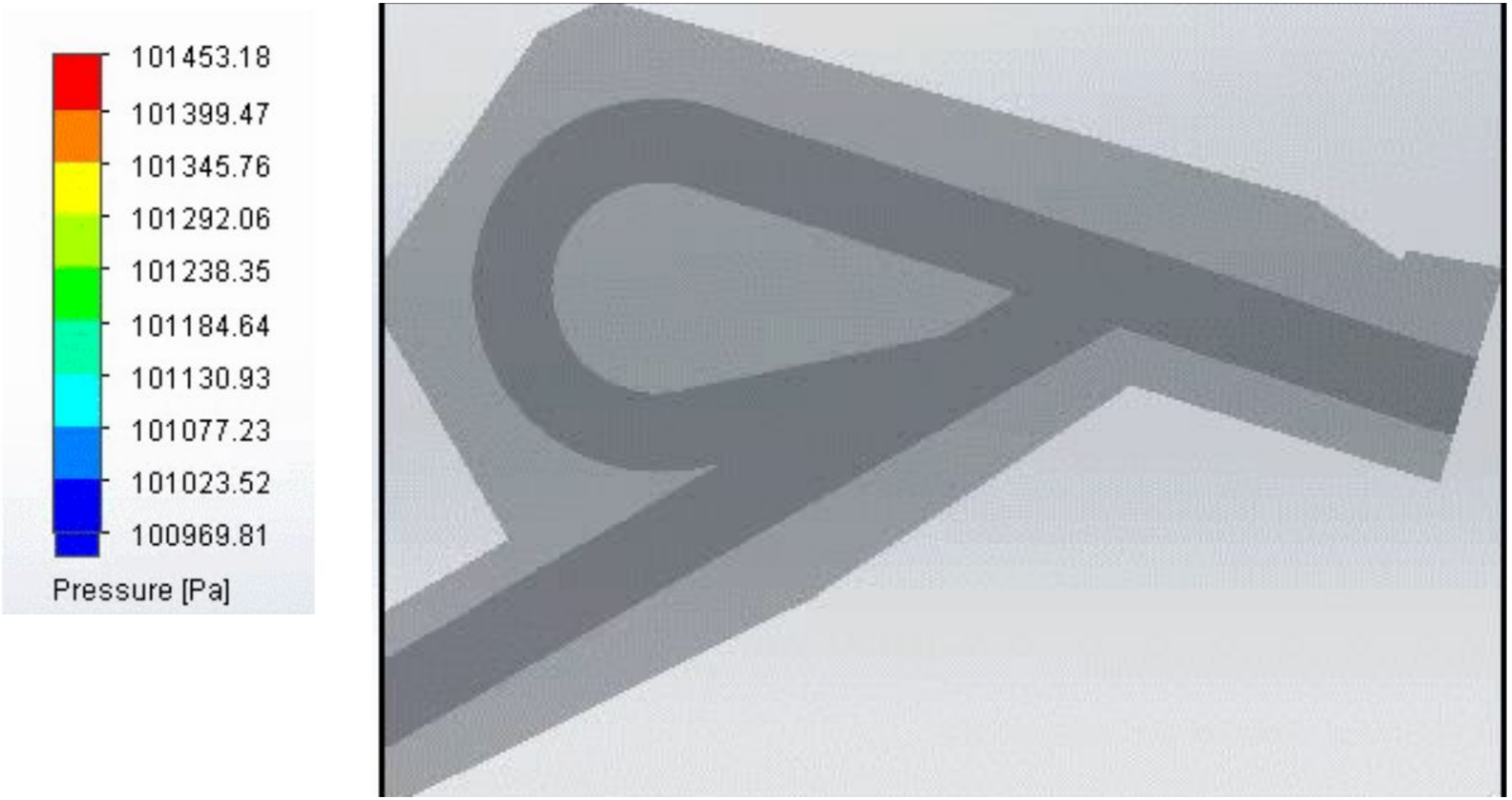
Forward Flow



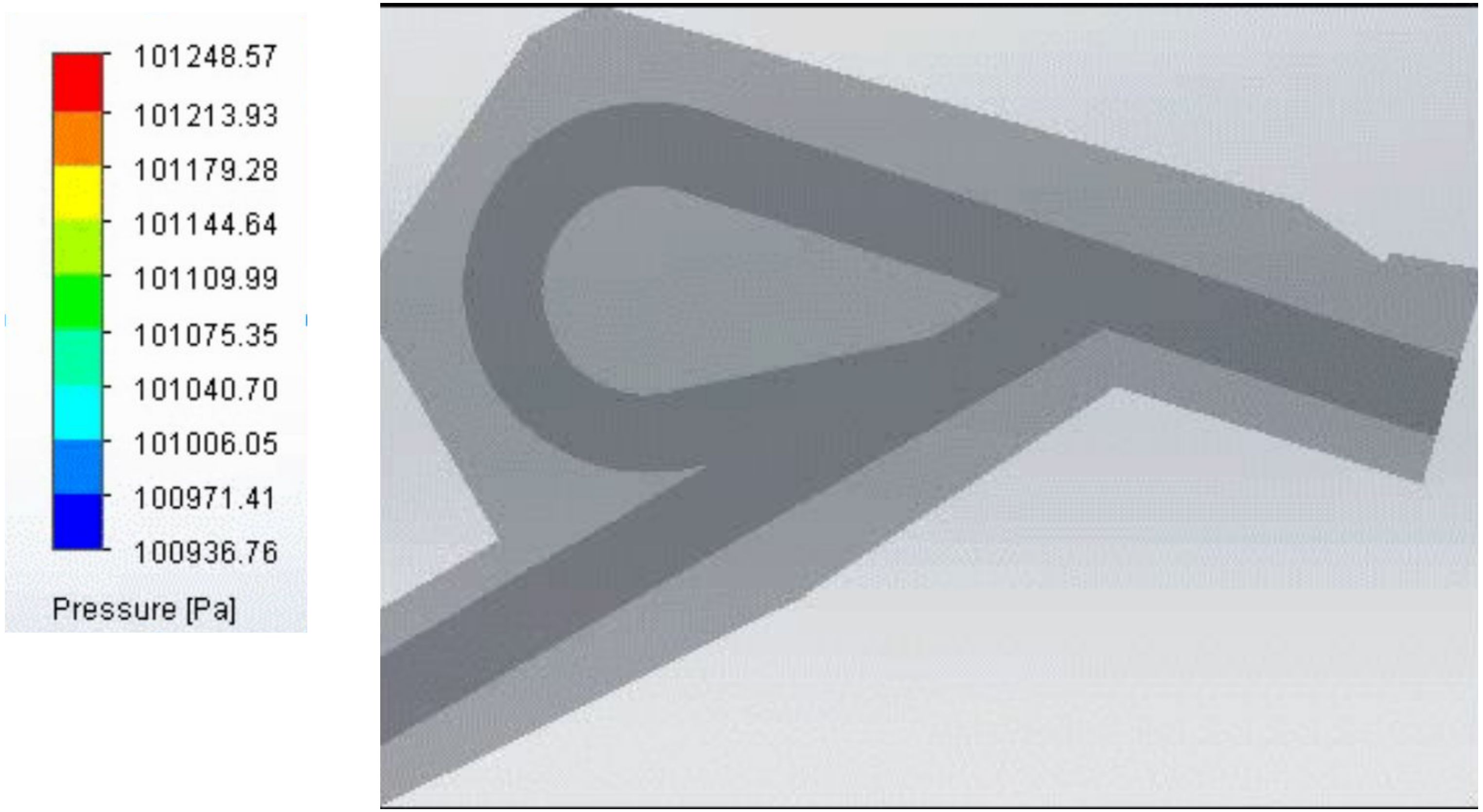
Reverse Flow



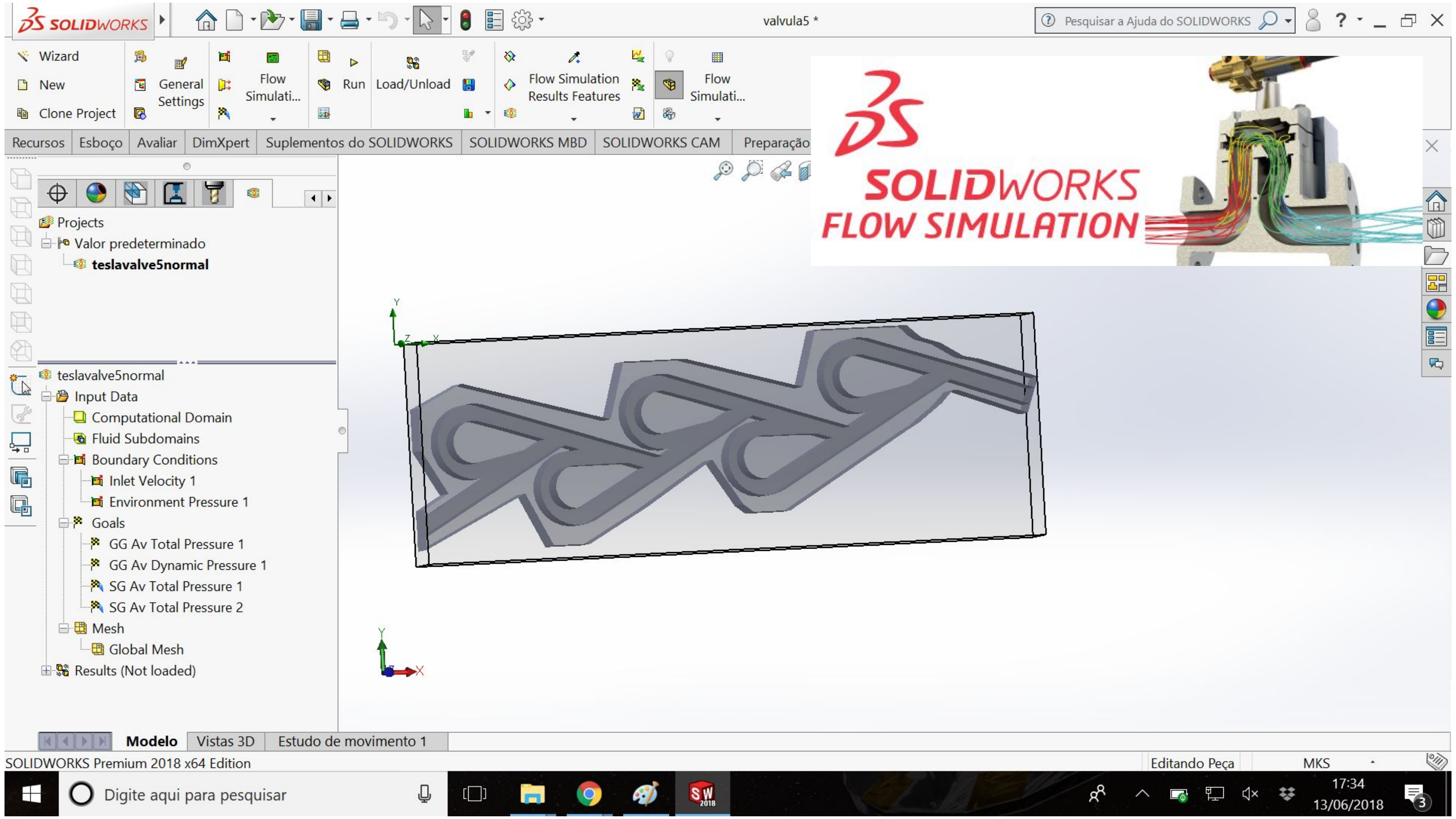
Qualitative Analysis: Reverse Flow



Qualitative Analysis: Forward Flow

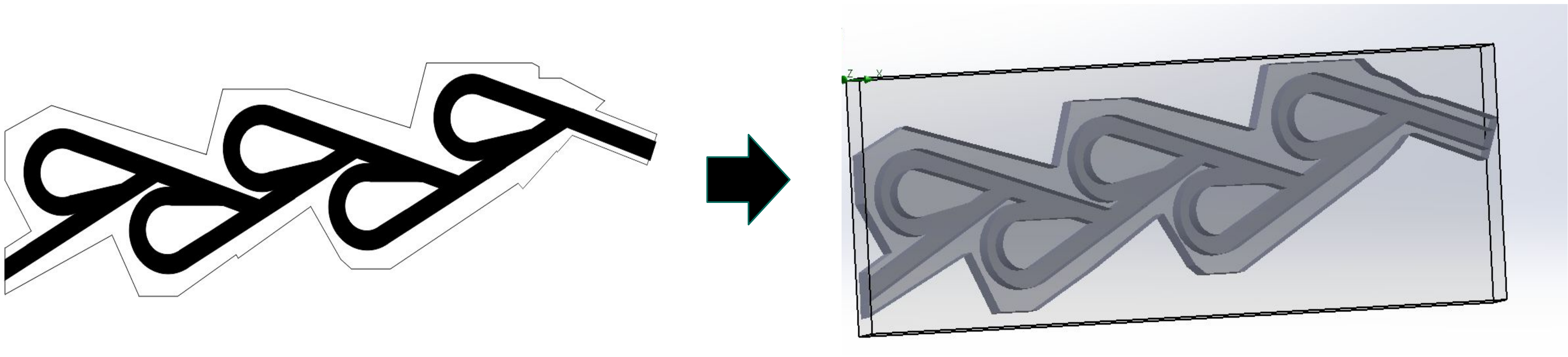


CFD Analysis: Solidworks Flow



CFD Analysis: 3D Modelling

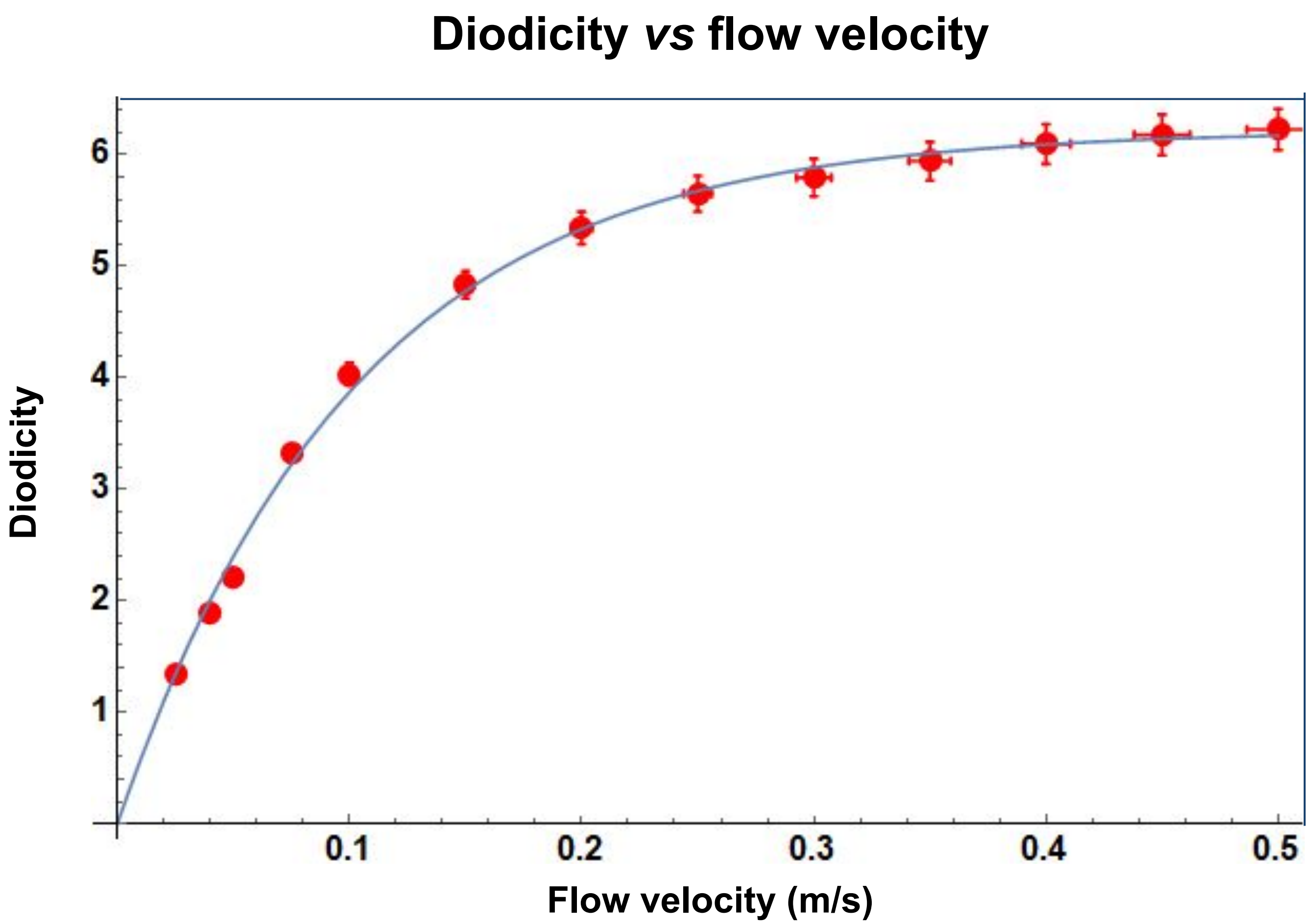
2D Profile → **Extrusion** → **3D Valve**



CFD Analysis: Relevant Parameters

- **Valve number** → **1 to 6 valves**
- **Valve size** → **2 cm to 0.2 cm**
- **Flow conditions** → **Flow velocity**
- **Valve format** → **Thomson or Patent**

CFD Analysis: Relevant Parameters



$$D = a(1 - e^{-bv})$$

$$< a >= 6.22 \pm 0.05$$

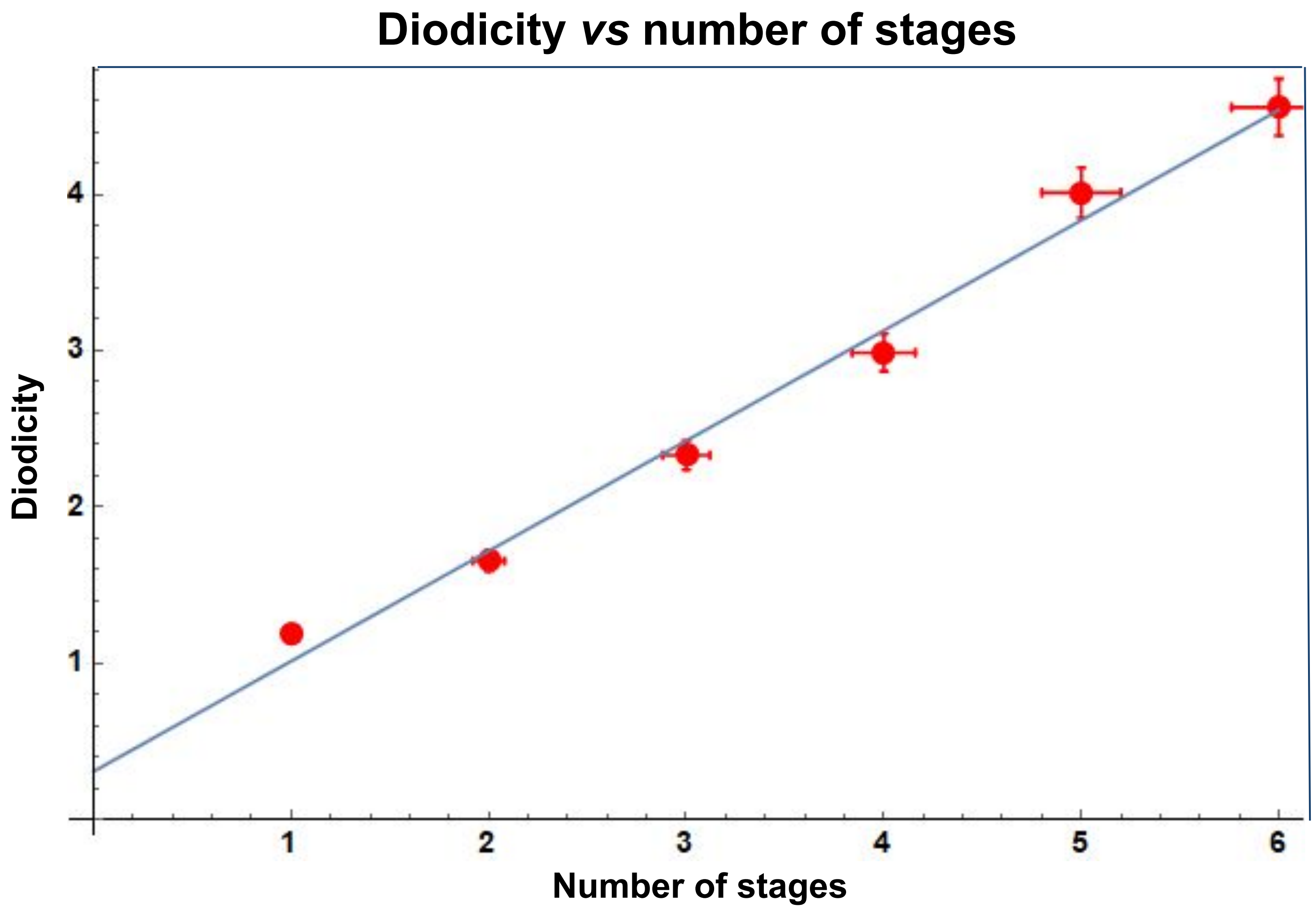
$$< b >= 9.8 \pm 0.3$$

$$D_{max} = lim_{\,v \to \infty} a(1 - e^{-bv})$$

$$D_{max} = a$$

Liquid: Water
n = 5
Thomson shape: L = 1cm

CFD Analysis: Relevant Parameters



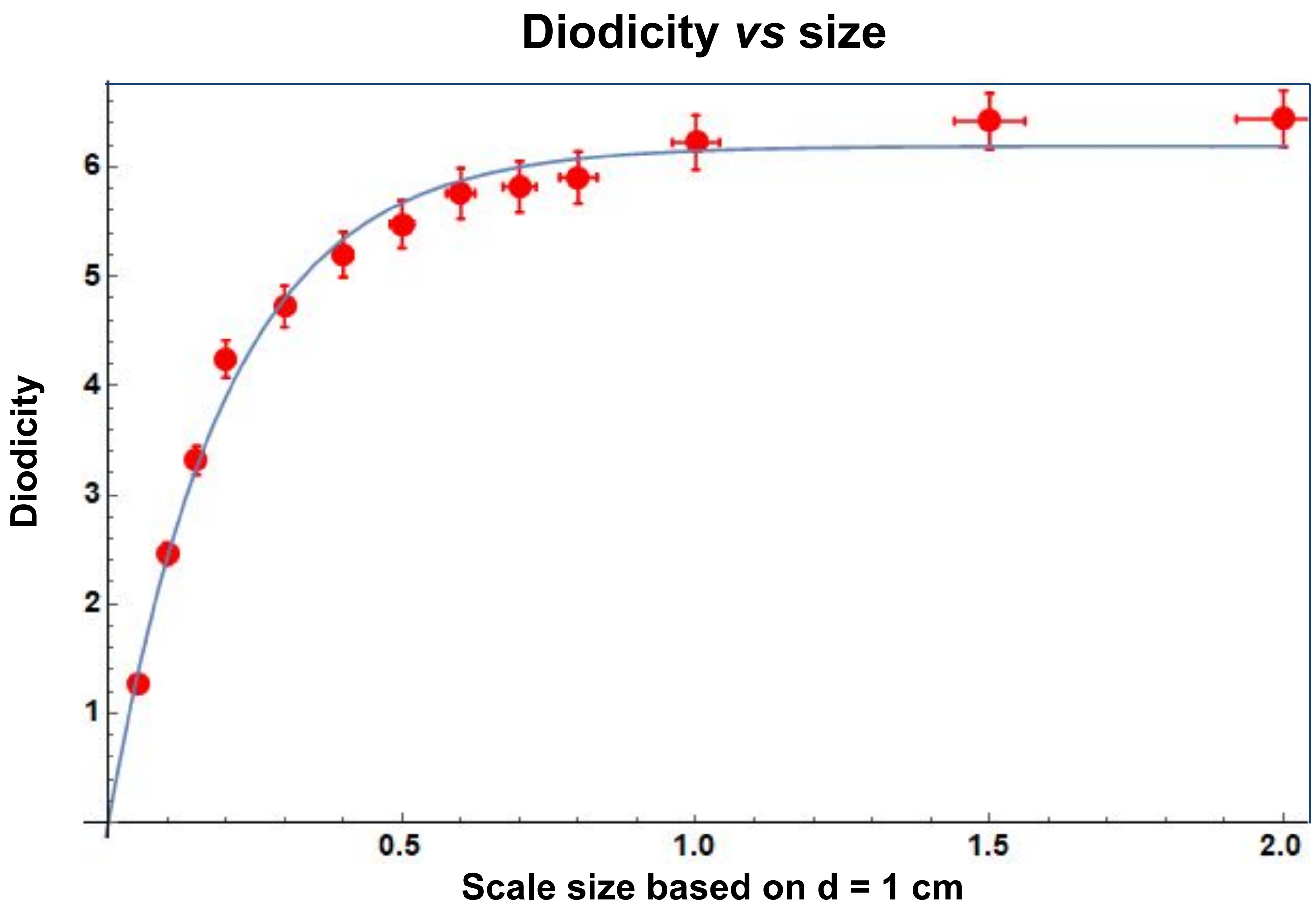
$$D = f + g \cdot n$$

$$f \approx 0.3 \pm 0.1$$

$$g \approx 0.70 \pm 0.04$$

Liquid: Water
V = 0.1 m/s
Thomson shape: L = 1cm

CFD Analysis: Relevant Parameters



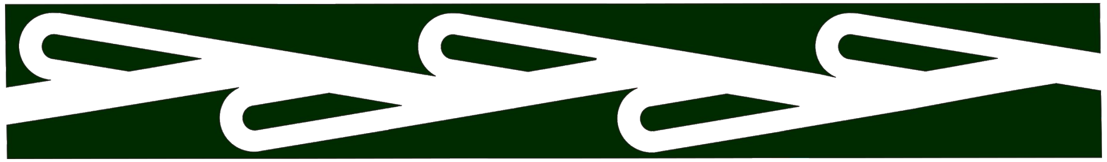
$$D = j(1 - e^{-k \cdot s})$$

$$j \approx 6.19 \pm 0.09$$

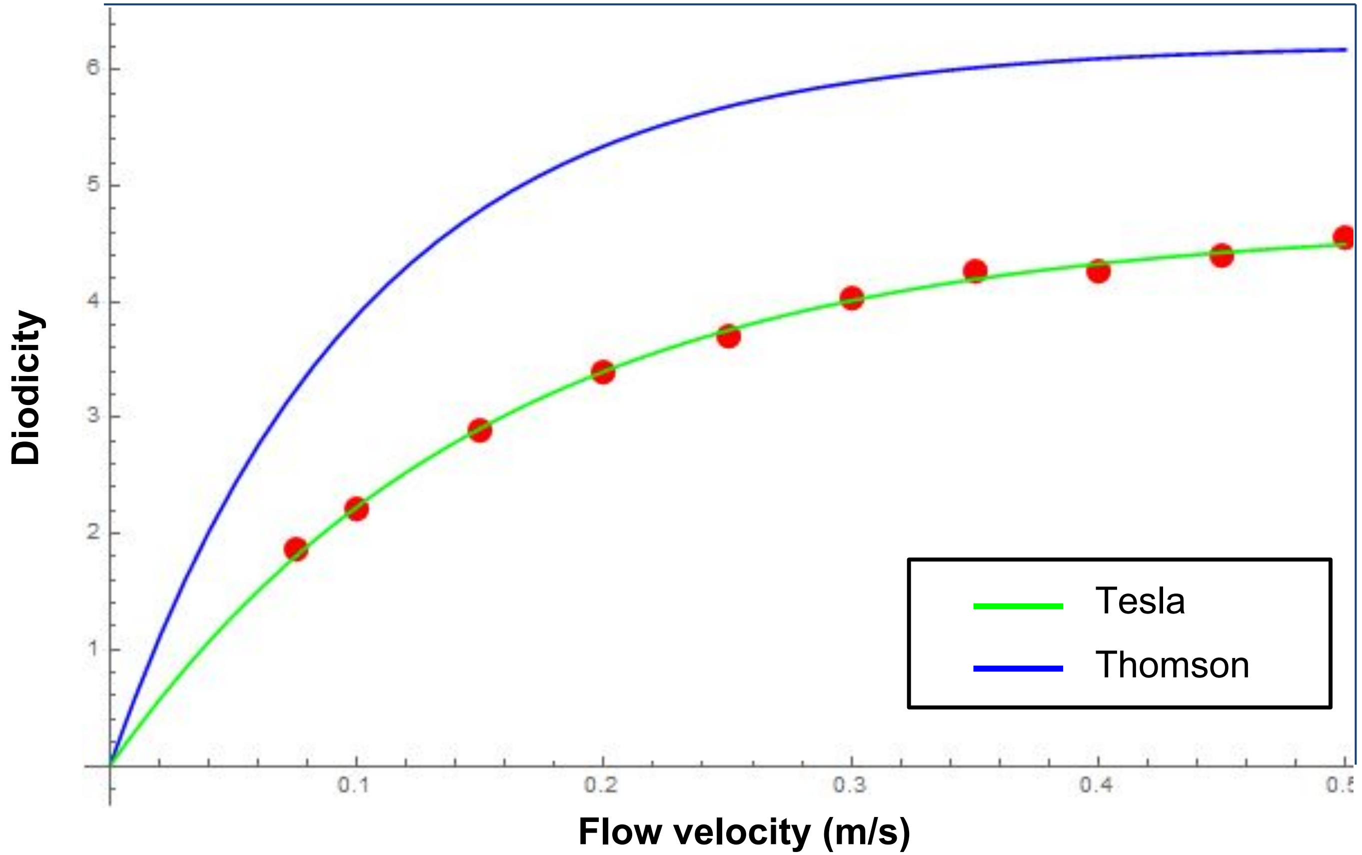
$$k \approx 5.0 \pm 0.3$$

Liquid: Water
V = 0.5 m/s
Thomson shape
n = 5 stages

CFD Analysis: Relevant Parameters



Diodicity of Tesla's design



Tesla's original design

$$D = a(1 - e^{-bv})$$

$$a \approx 4.68 \pm 0.04$$
$$b \approx 6.5 \pm 0.2$$

Liquid: Water
V = 0.5 m/s
Tesla shape
n = 5 stages

CFD Analysis: Conclusion

Flow Velocity

$$D = a(1 - e^{-bv})$$

Number of stages

$$D = f + g \cdot n$$

Scale size

$$D = j(1 - e^{-k \cdot s})$$

General Equation

$$D(n, v, s) = V_0 + V_c \cdot (1 - e^{-bv})(1 - e^{-ks}) \cdot n$$

Experimental Materials

1 - Multiple valves cutted from acrylic sheets

2 - YF-S201 Flow sensors (E = ± 2.25 ml)

3 - BMP180 Sensors (E = ± 1 Pa)

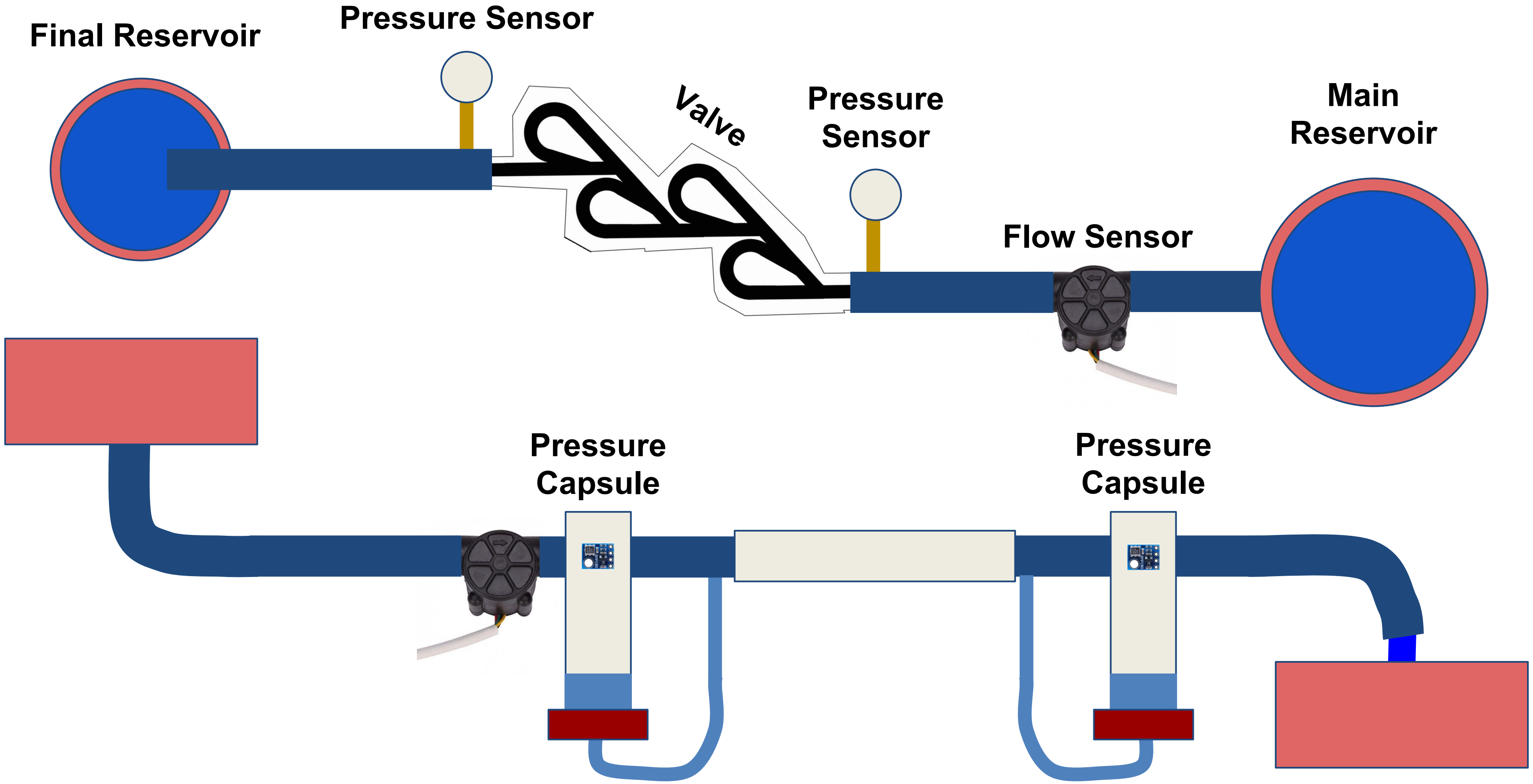
4 - 150mm PVC Tube

5 - 20 mm and 6mm clear tubes

6 - Silicone Sealant

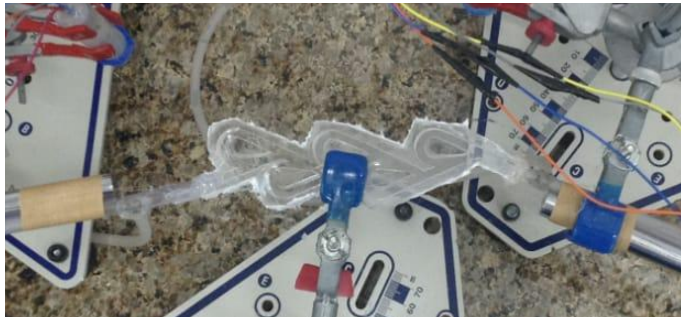
7 - A computer connected to Arduinos

Experimental Set-up: Test Rig

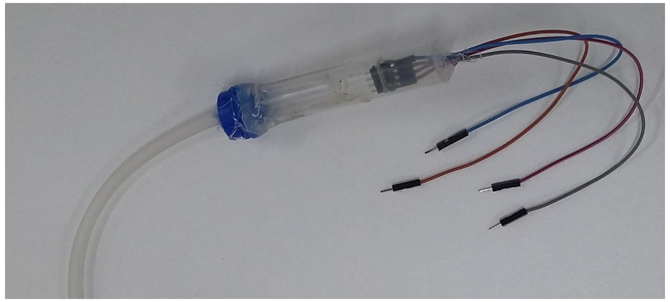


Experimental Set-up: Test Rig

Valve Placement



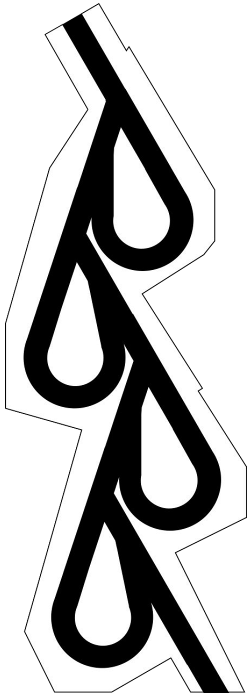
Pressure Capsule



Hydraulic System

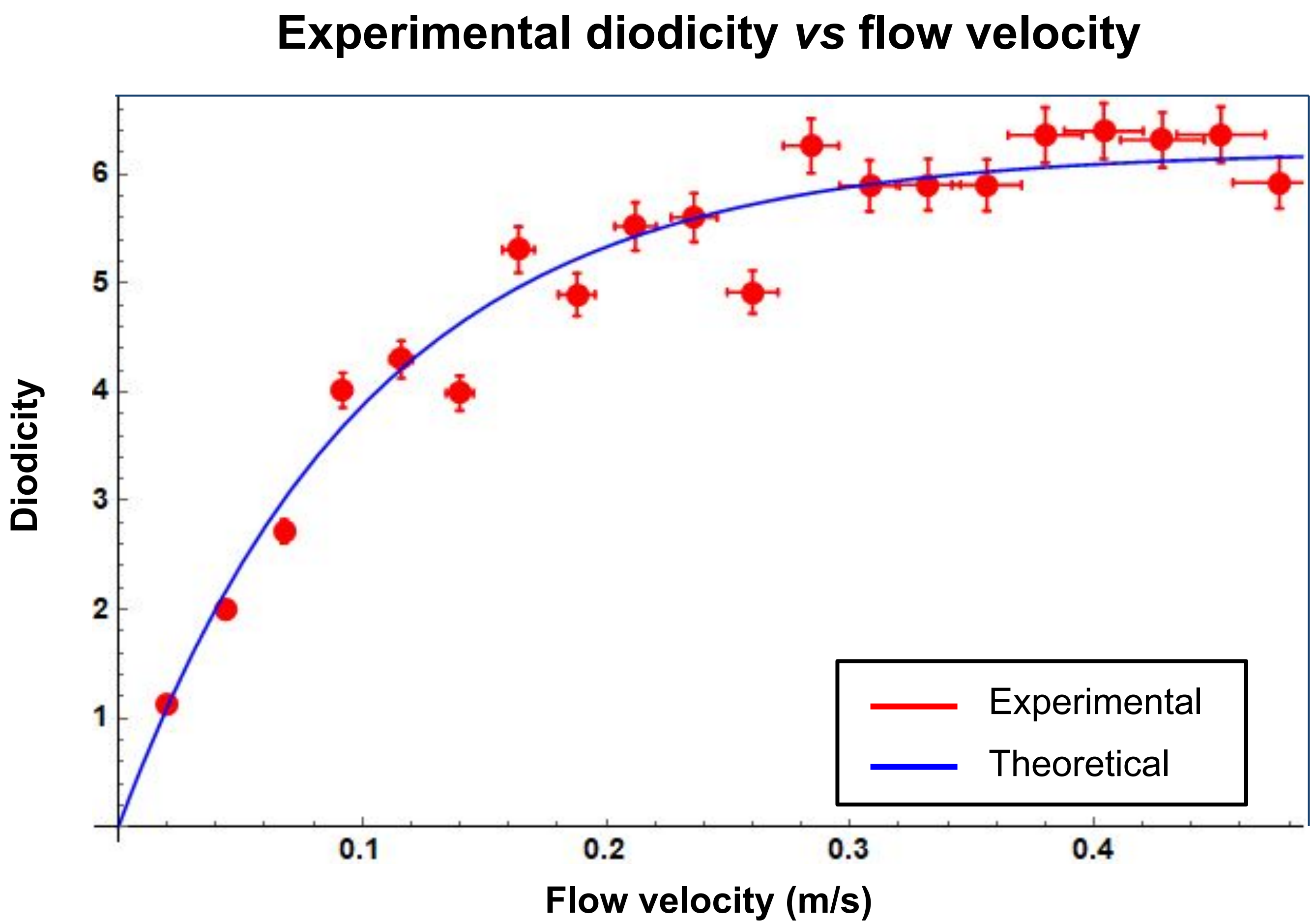
Experimental Set-up: Test Rig

2D Laser Cutting



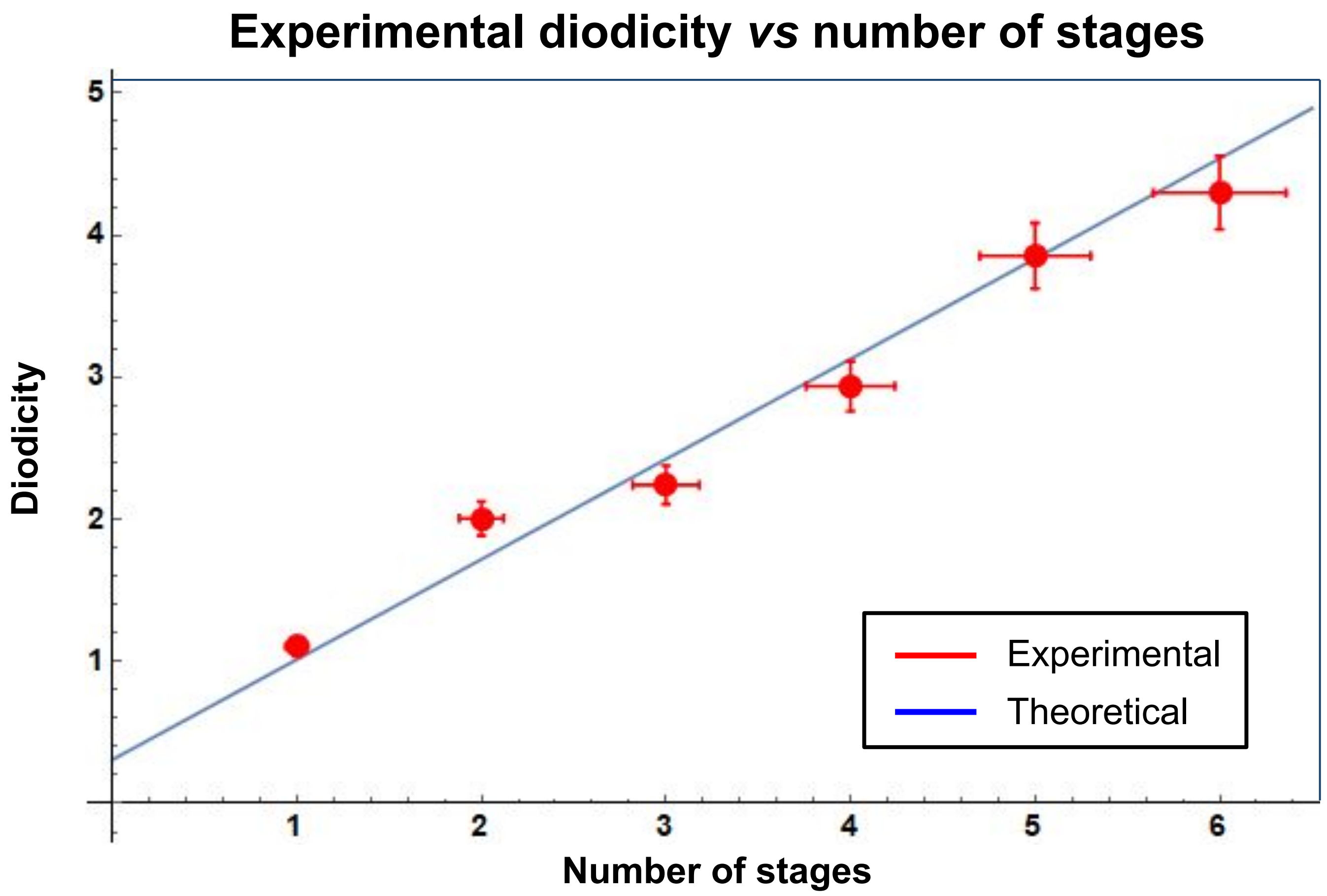
Clear Crystal Acrylic Sheets

Experiment 1: Flow Velocity



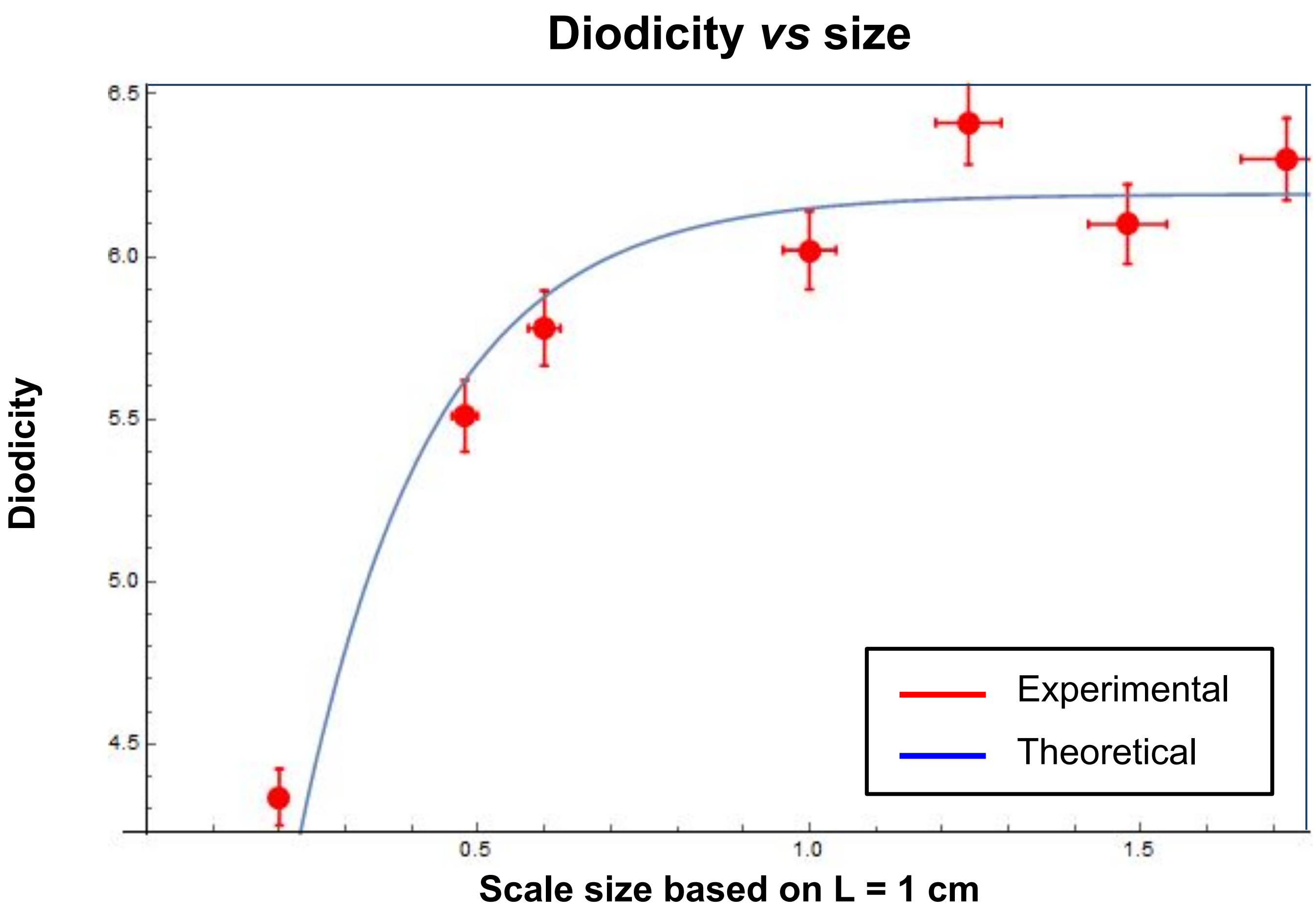
Liquid: Water
n = 5
Thomson shape
L = 1cm

Experiment 2: Number of Stages



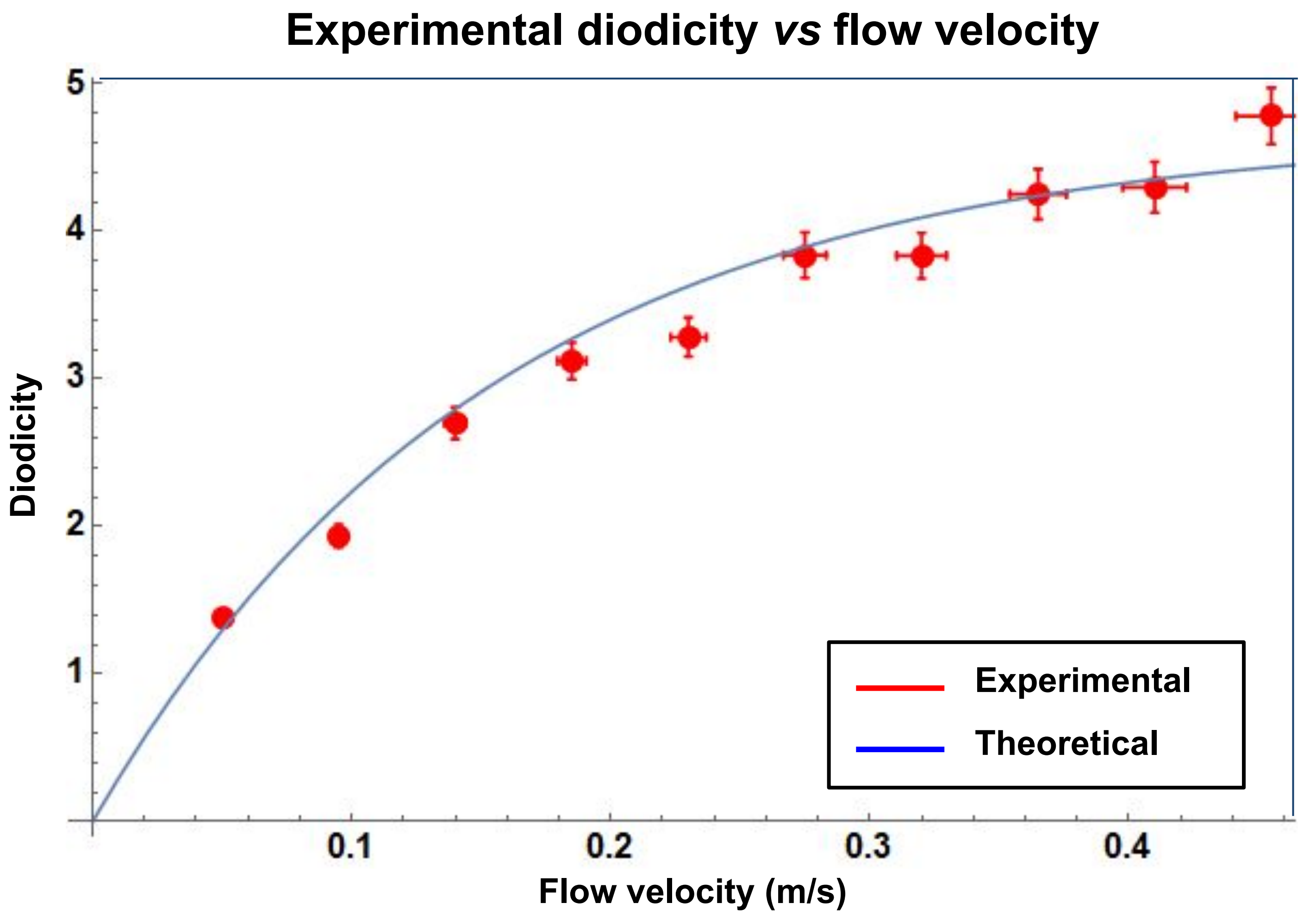
Liquid: Water
v = 0.1 m/s
Thomson shape
L = 1cm

Experiment 3: Scale Size



Liquid: Water
v = 0.5 m/s
Thomson shape
n = 5 stages

Experiment 5: Flow Velocity in Patent Format

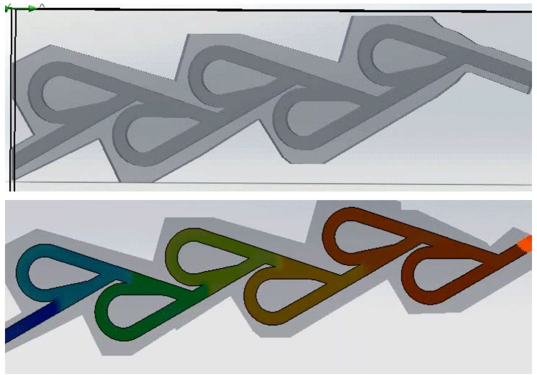


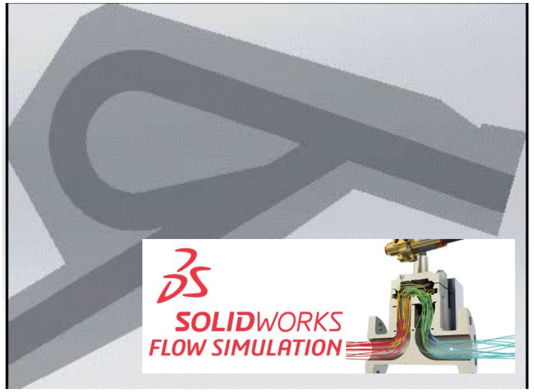
Liquid: Water
n = 5
Tesla shape
L = 1cm

Summary: Theory

Diodicity

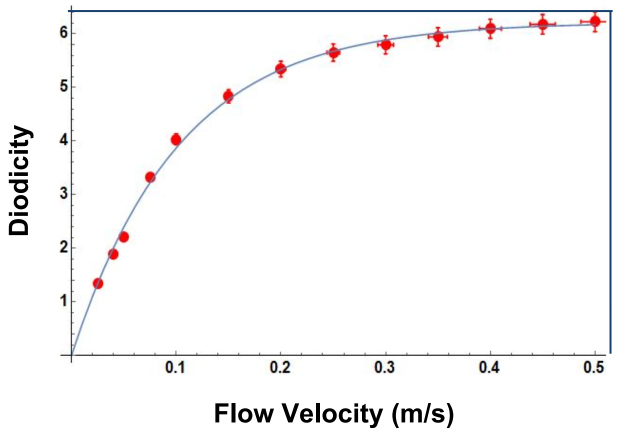
$$D = \frac{\Delta P_r}{\Delta P_f}$$



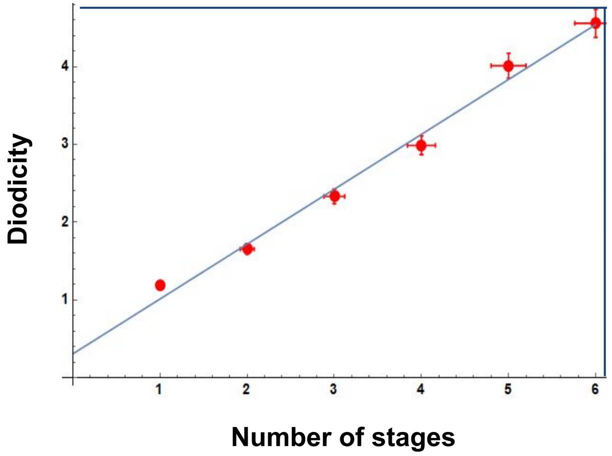


$$D(n, v, s) = V_0 + V_c \cdot (1 - e^{-bv})(1 - e^{-ks}) \cdot n$$

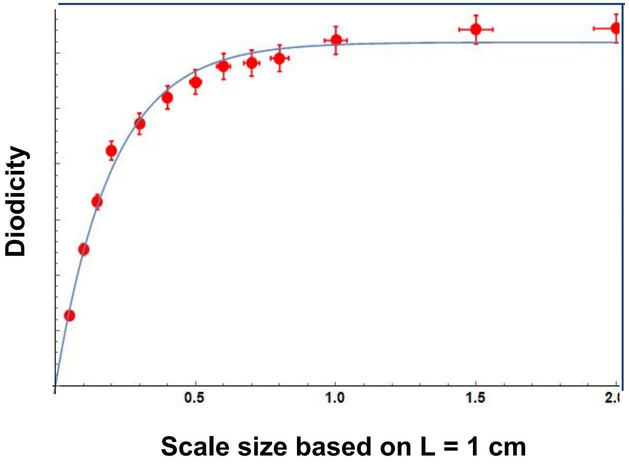
Diodicity *vs* flow velocity



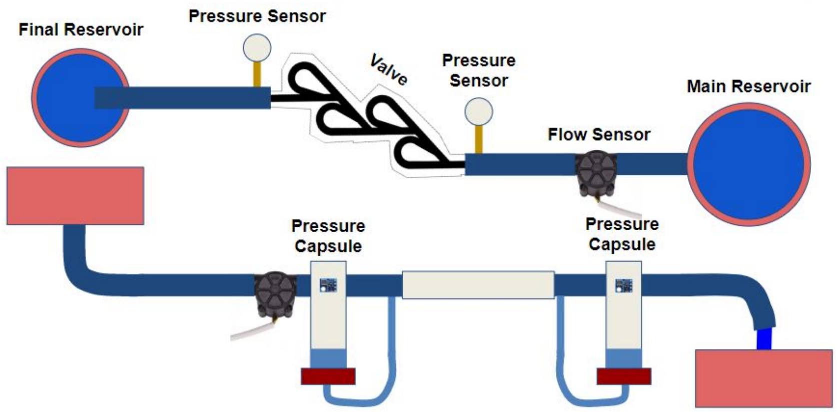
Diodicity *vs* number of stages

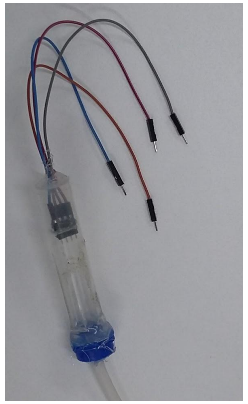


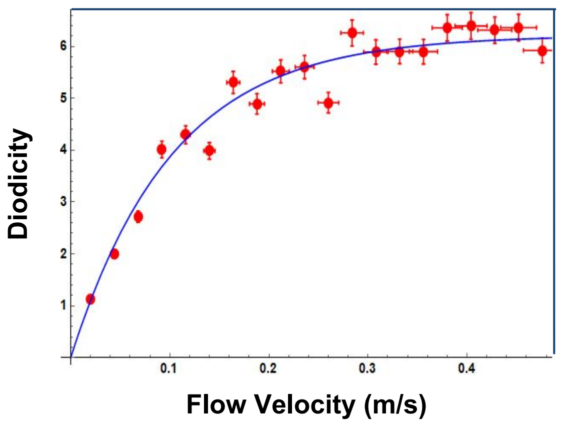
Diodicity *vs* size

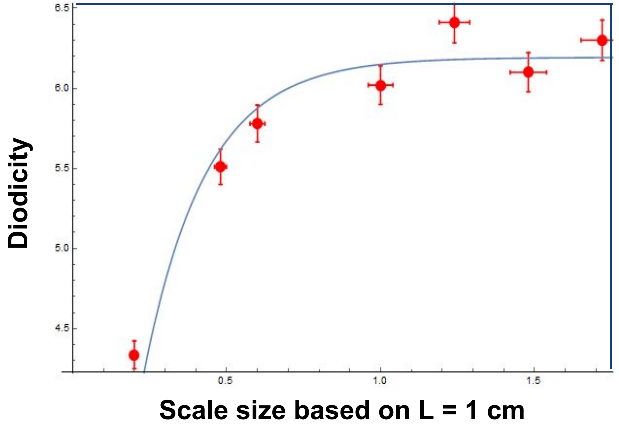


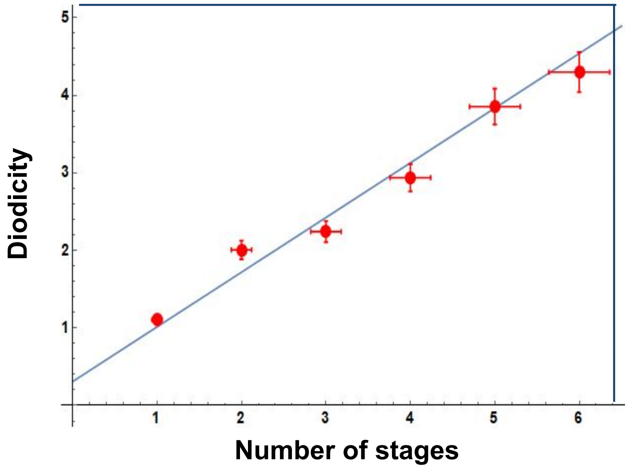
Summary: Experiments











Bibliography

[1] Tosun, I., Uner, D., & Ozgen, C. (1988). Critical Reynolds number for Newtonian flow in rectangular ducts. Industrial & Engineering Chemistry Research, 27(10), 1955–1957. https://doi.org/10.1021/ie00082a034

[2] Thompson, S. M., Walters, D. K., Paudel, B. J., & Jamal, T. (2013). A Numerical Investigation of Multi-Staged Tesla Valves. In Volume 1A, Symposia: Advances in Fluids Engineering Education https://doi.org/10.1115/fedsm2013-16269

[3] Tesla, N. (1920). Valvular conduit. 1,329,559.a

Thank you!