



Biosensing Microfluidics Presentation

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Table of contents

01 Background

03 Project Impact

02 Project Work



01

Background





What Does this Aim to Solve?

- ❖ There are several issues related to blood testing that face people across the world, and this disposable cartridge system aims to solve many of them, including:
 - **High cost** of blood tests
 - **Inconvenience** of blood testing
 - Limited **access** (especially in remote areas)
 - Clinic Visits
 - Contamination Risk
 - **Slow time** for results/ diagnosis
 - Inefficient use of resources for blood testing
 - Difficulty in **monitoring health** regularly (late detection of conditions)

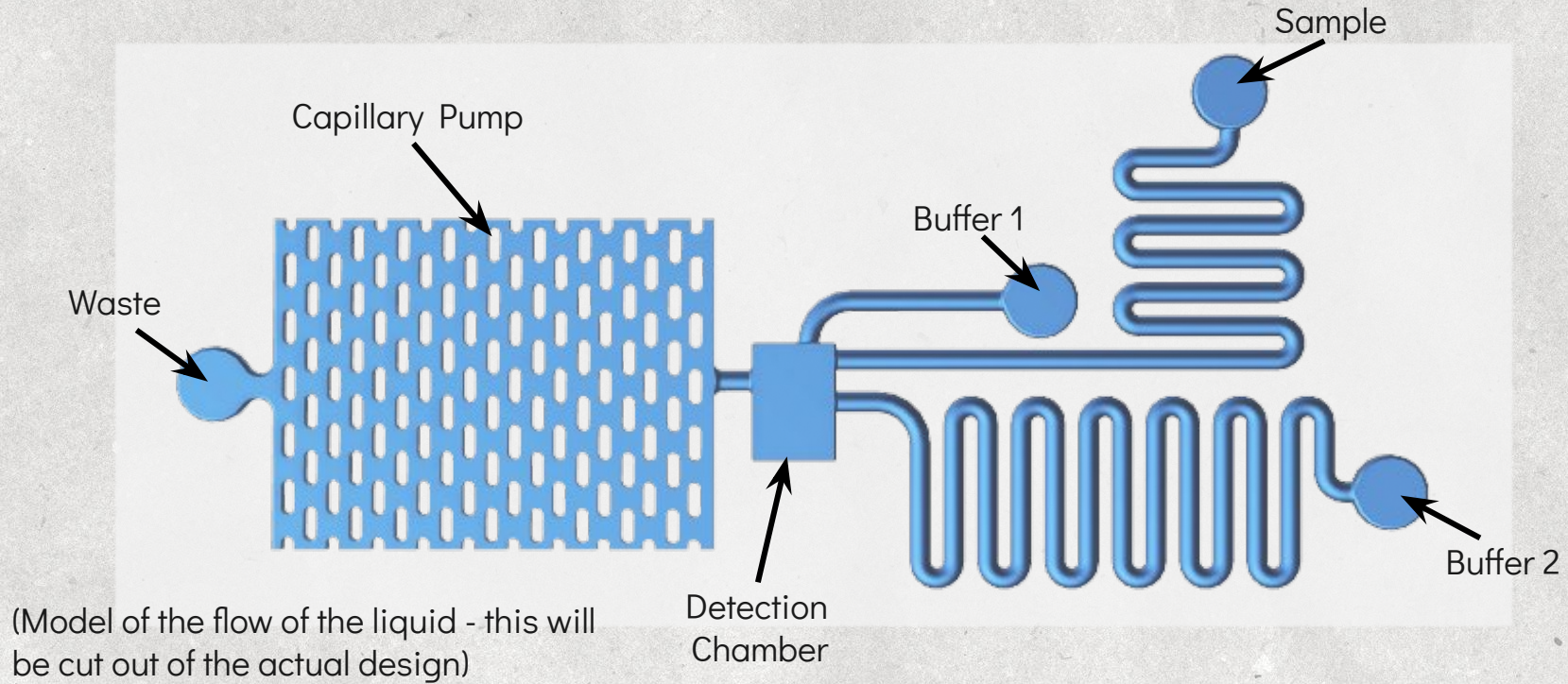


Benefit of This Project

- ❖ **Cost-effective testing**
 - Uses inexpensive materials (plastic cartridge, streamlined CNT manufacturing process)
 - No electricity – chip is separate from cartridge
- ❖ **Minimal Discomfort**
 - Only requires a drop of blood for accurate testing
- ❖ **Portable & Accessible**
 - Very easy to use & store the cartridge - small devices
 - Easy for both hospital use and remote/ individual use
- ❖ **Time-Saving/ Rapid Results**
 - Can conduct tests at home - no need to go to clinic
 - Receive results back within a few minutes
 - See results on mobile device - connected through an app
- ❖ **Reduced Risk of Contamination**
 - Blood tests are not grouped with others
 - Disposable cartridges ensure for accurate & reliable tests
- ❖ **Better Health Monitoring**
 - Can take tests frequently to constantly monitor health & pathogen presence
 - Can see results & history through the secure mobile app



Biosensing Cartridge Design



Diving Deeper: Biosensing Cartridge Explanation

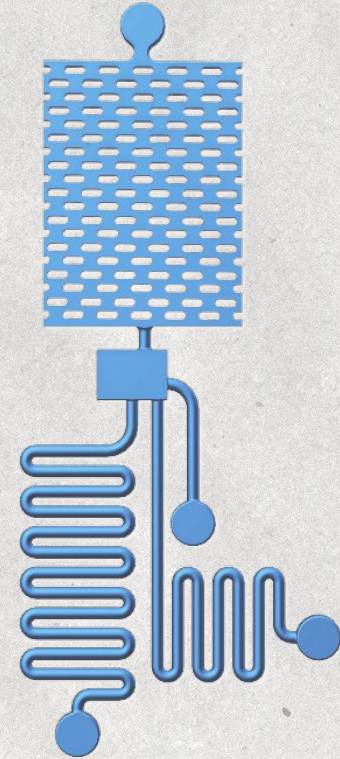


[Microfluidics Reference \[Linked\]](#)

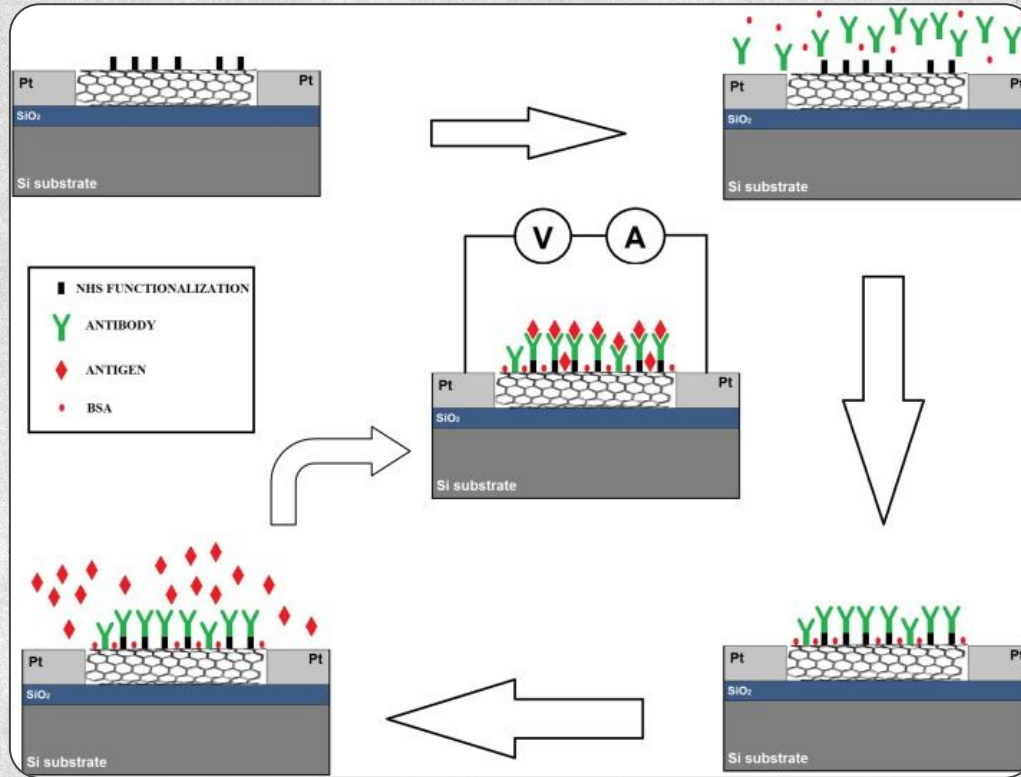


Description of the parts of the cartridge:

- Buffer 1
 - PBS buffer – before any solutions enter
 - Acts as a control
- Sample
 - This is the blood sample – a drop of blood from the patient
 - After Buffer 1 fully goes to the waste
- Buffer 2
 - PBS buffer - clears out extra blood particles left on the CNTs in the detection chamber
 - After the sample fully goes to the waste
- Detection Chamber
 - Filled with CNTs, each group of CNTs are functionalized for certain biomolecules
 - The CNT receptors bind to the blood biomolecule
 - The change in electrical charge from the presence of the target biomolecule is measured by a chip below – this provides result data
- Capillary Pump
 - The entire system utilizes capillary action – thin tubes
 - This gradient of holes allows for more effective capillary action – decreases pressure inside the system
- Waste
 - All liquids empty out here - to be disposed after testing



CNT Detection Chamber Visualization





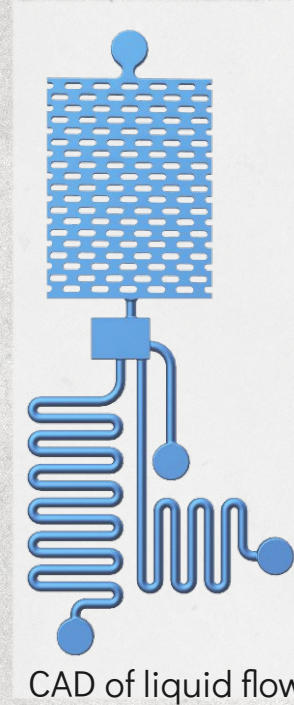
02

Project Work

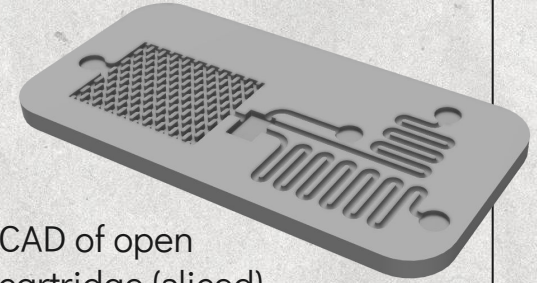


Cartridge Design

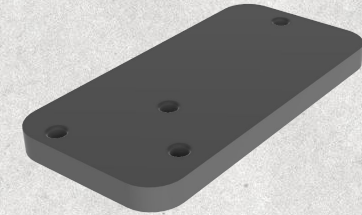
- ❖ I designed the CAD model for the cartridge – used the [Microfluidics Reference](#) and some previous basic models as reference
 - On Autodesk Fusion 360
- ❖ 1mm wide pipe
- ❖ Detection chamber varies based on chip detection size
 - Pros/ Cons of a smaller chamber
 - Pros:
 - Faster detection
 - Liquid goes all around chamber
 - PBS buffer cleans chamber more thoroughly
 - Cons:
 - May not have enough CNTs for accurate detection
 - May not accommodate detection chip sensor



CAD of liquid flow



CAD of open cartridge (sliced)

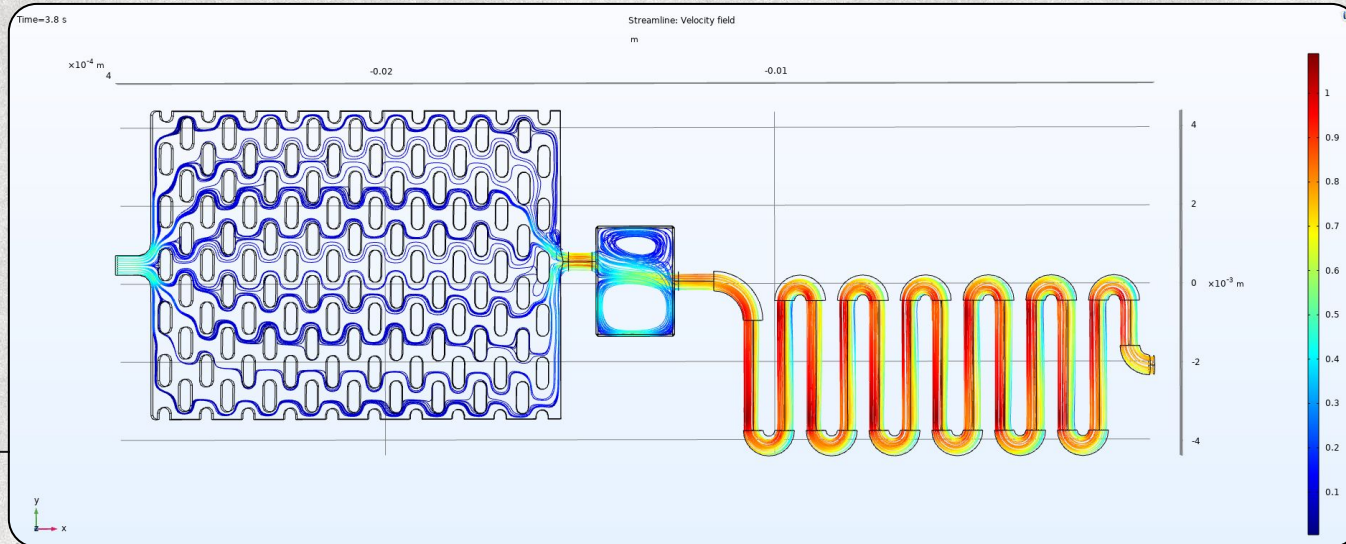


CAD of closed cartridge (with holes for substance/ liquid input)



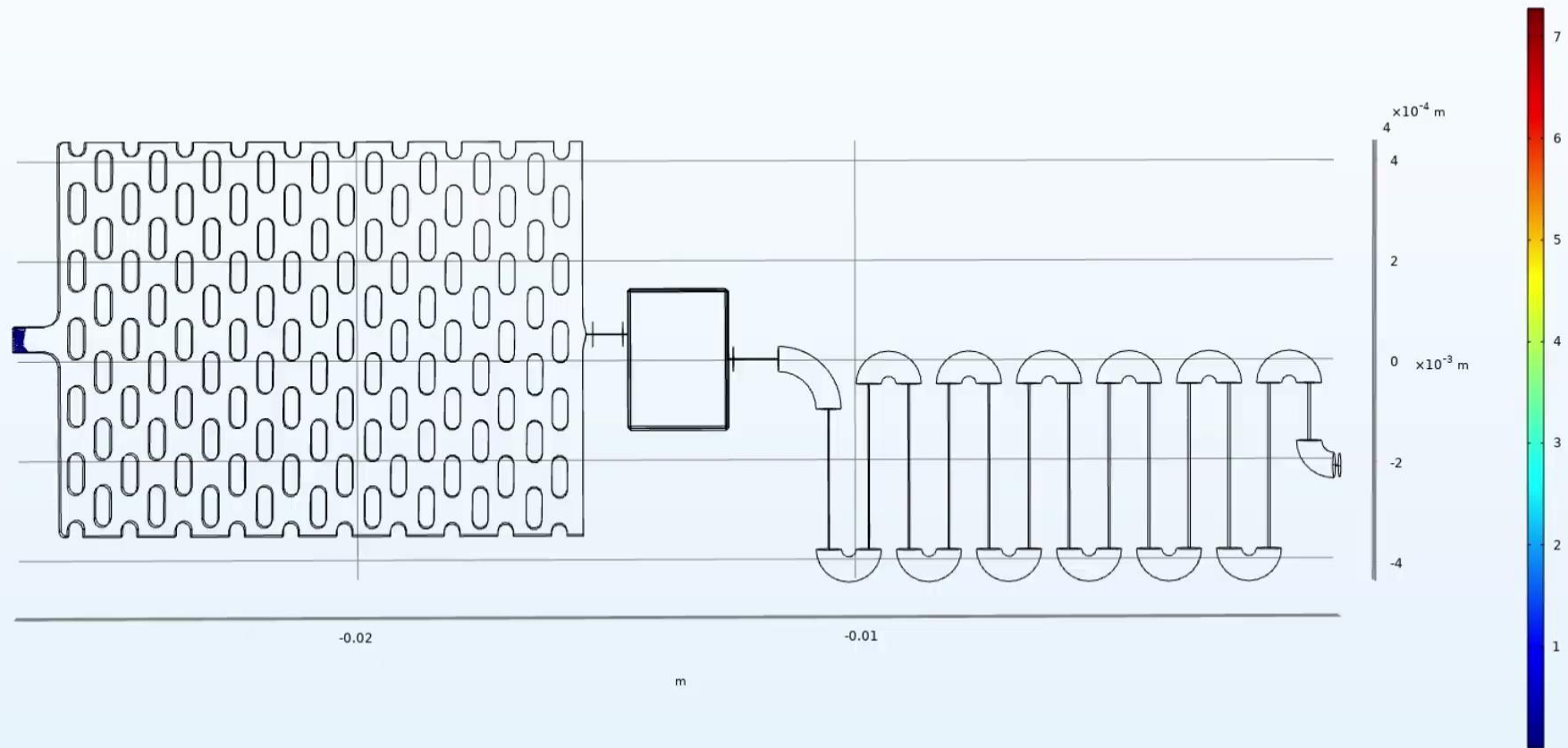
COMSOL Model - Laminar Flow

- ❖ COMSOL Multiphysics Software
- ❖ Simulated Laminar Flow throughout the system
- ❖ Assumed water as the solution
 - Similar to the PBS buffer solution (saline solution)
- ❖ Did not consider capillary calculation (ran into errors during capillary action simulation)
- ❖ Helps show ratios of water velocity throughout the system
 - Will likely be a more even spread of velocity with capillary action
- ❖ Ran simulation for a single input source



Time=0 s

Streamline: Velocity field



Flow Rate Calculations

- ❖ Equations/ Formulas Used:
 - Capillary Pressure Barrier (ΔP)
 - Flow Rate (Q)
 - Used another viscosity value to calculate flow rate for blood - not shown in calculations
 - Fluidic Resistance (R)
 - Velocity (V)
 - Time (t)

❖ [Scratch Work \(PDF\)](#) [\[Linked\]](#)

Capillary pressure (P_a)

$$P_{cap} = \gamma \left(\frac{\cos \theta_{top} + \cos \theta_{bottom}}{h} + \frac{\cos \theta_{left} + \cos \theta_{right}}{w} \right)$$

↑
surface tension

$$Q = \frac{P_{cap}}{\eta R_F}$$

Flow Rate ($\frac{m^3}{sec}$)

Viscosity ($\frac{N \cdot s}{m^2}$)

Capillary Pressure (P_a)

Length h

$$R_F = \frac{8h}{\pi r^4}$$

radius of pipe (m)

Velocity ($\frac{m}{s}$)

$$Velocity = \frac{Q}{\pi r^2}$$

Time (s)

$$Time = \frac{h}{v} = \frac{\text{Pipe Length}}{\text{Velocity}}$$



Tube Length vs. Time

- ❖ Tube Length (h)
 - Assumed tube diameter of 1mm
 - In mm
- ❖ Time (T)
 - In seconds
- ❖ Points on the graph:
 - Each point represents the:
 - (Length of pipe, time from start to end of pipe) for each of the 3 input holes (buffer 1, sample, buffer 2)
 - Buffer 1:
 - 50mm long, 0.543 seconds
 - Blood:
 - 65 mm long, 4.057 seconds
 - Buffer 2:
 - 179 mm long, 7.061 seconds

$$T = \left[\frac{(h)(\pi)(0.0005)^2}{\left(\frac{0.1444}{h} + 144.4\right)(\pi)(0.0005)^4} \right] \text{ sec}$$

Graph on Next Slide →



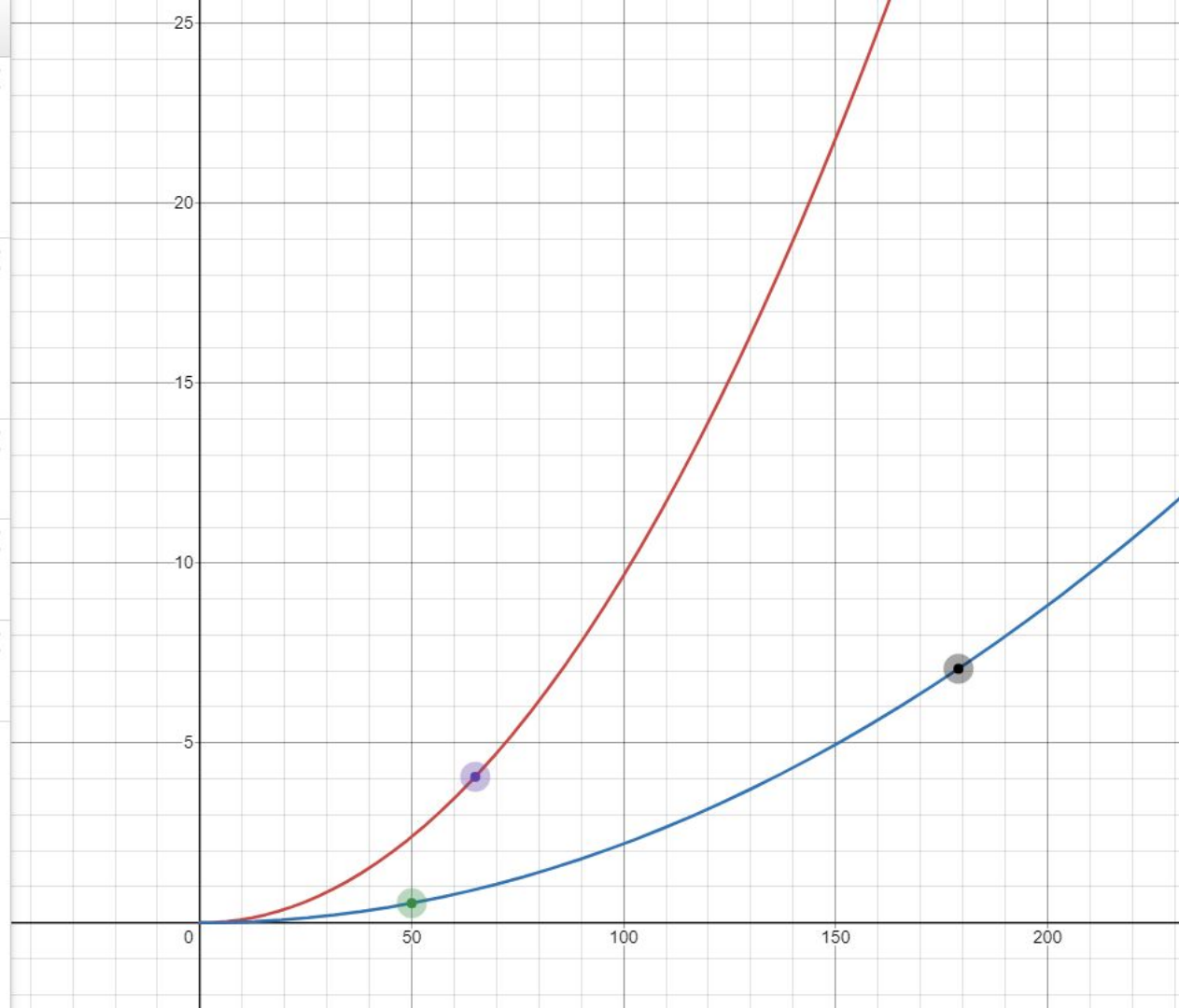
$$T_{blood} = \frac{(4.4 \cdot 10^{-3})(s) \left(\frac{h}{1000} \right) \left(\frac{h}{1000} \right) (\pi) (0.0005)}{\left(\left(144.4 + \frac{0.1444}{\left(\frac{h}{1000} \right)} \right) (\pi) (0.0005)^4 \right)}$$

$$T_{pbs} = \frac{(1 \cdot 10^{-3})(s) \left(\frac{h}{1000} \right) \left(\frac{h}{1000} \right) (\pi) (0.0005)}{\left(\left(144.4 + \frac{0.1444}{\left(\frac{h}{1000} \right)} \right) (\pi) (0.0005)^4 \right)}$$

$$x_{buffer1} = (50, 0.543)$$

$$x_{blood} = (65, 4.057)$$

$$x_{buffer2} = (179, 7.061)$$



Van Der Waals Calculations

- ❖ Equations/ Formulas Used:
 - Van Der Waals Force (F)

- ❖ [Scratch Work \(PDF\) \[Linked\]](#)

$$F_{vdw}(r) \approx 6.944 \times 10^{-12} \text{ N}$$

$$F_{vdw}(r) = - \frac{AR_1R_2}{(R_1+R_2)6r^2}$$

Unit Check: $\frac{\text{J} \cdot \text{m} \cdot \text{m}}{\text{m} \cdot \text{m}^2} = \frac{\text{J}}{\text{m}} = \text{N} \checkmark$

F_{vdw} = Van der Waals force (N)
 A = Hamaker constant (J)
 R_1 = Radius of CNT (m)
 R_2 = Radius of biomolecule (m)
 r = Distance between surfaces (m)





03

Project Impact



The Goal of Calculations

- ❖ We are trying to find out the necessary amount of force by the PBS buffer (Buffer 2) to effectively clear the detection chamber of the blood (Sample) residue.
 - Due to Van Der Waal forces, blood that is not meant for the receptors of the CNTs attaches to the CNTs
- ❖ These calculations aim to answer the following questions based on capillary forces (as well as give a better general understanding of the liquids in the system and their velocities/ flow rates):
 - Is our liquid being effectively moved by capillary action in the system?
 - What is the Van Der Waals force between blood and the CNTs?
 - Is the velocity of our water enough to push off blood molecules attached to CNTs by Van Der Waals forces?
 - What should the pipe lengths be to allow each liquid to be released about 3.5 seconds after one another (based on capillary action)?



How does this help us?

- ❖ These calculations will allow us to ensure that our model supports the right flow rates, and allows us to prototype more accurately. There may be external factors that influence the capillary action which the theoretical calculations do not consider, but it is good to have a theoretical to understand what other variables may be influencing the model during actual testing. Using these calculations, we can make sure that testing is accurate, as blood molecules left on the CNTs will be washed fully by buffer 2.
- ❖ In summary, these calculations will help us:
 - Understand the cause of other variables that impact change during prototyping
 - Have accurate blood tests with the cartridge

