LAB Microfluids - Lab Procedure

INTRODUCTION

The purpose of this lab is to provide the student with an opportunity to investigate microfluidic properties and benchmark an existing generic lab-on-a-chip design. The student will utilize clear water to test channels and overall chip design and functionality using a provided generic acrylic chip along with an improved sealing apparatus and related equipment and tools.

Students will determine the sealing and fluid delivery capabilities of the generic design and use insight gleaned from this lab to understand design considerations in building a better chip. Students will understand the importance of benchmarking, reverse engineering, and synthesis in creating improved designs.

PROCEDURE

Segment A: MEASURING CAPILLARY VALVE EFFECTS

1. Fill a beaker with tap water.

2. Dip the capillary tube about half way into the water and pull it out after covering the top hole with your finger to hold the water in the tube.

3. Drain the capillary slowly by gradually releasing the seal on the back of the tube with your finger. Do not touch or tap off the suspended drop. Be sure to hold it vertically!

4. Mark this water height with felt tip marker in your kit.

5. After marking, touch the bottom of the tube to the water surface in the cup without submerging much of the tube. You should see the level drop but not completely evacuate the tube.

6. Mark this second water height.

7. Measure and record gap between the two marks, $\Delta h$.

8. Repeat steps 3 through 9 three times.

9. Repeat steps 3 through 10 with the other capillary tube.

10. Record the results in Worksheet A.
NOTE: In this lab, all units should be in meters (m), kilograms (kg), seconds (s), kilograms per meter-second squared (kg/m-s²) for pressure. For your information, 1" = 2.54 cm. 1 cm³ = 1 mL.

Pressure: 1 Pa = 1 N/m² = 1 (kg/m²)(m/s²) = 1 (kg/m-s²).

Newtonian Fluid Properties and Relationships:

Fluid Flow Rate Through a Capillary

Cross-sectional area of capillary

\[ A_{\text{cap}} = \pi r_{\text{cap}}^2 \]

Change in pressure (Figure 3)

\[ \Delta P = -\rho_f g \Delta h \]

![Figure 3: Capillary fluid height and resulting difference in pressure.]

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
<th>Constant Given</th>
<th>Preferred Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_f )</td>
<td>Density of fluid (water)</td>
<td>998.2</td>
<td>kg/m^3</td>
</tr>
<tr>
<td>( g )</td>
<td>Acceleration of gravity</td>
<td>9.81 m/s^2</td>
<td>m/s^2</td>
</tr>
<tr>
<td>( A_{\text{cap}} )</td>
<td>Cross-sectional area of capillary</td>
<td>&lt;&gt;</td>
<td>m²</td>
</tr>
<tr>
<td>( r_{\text{cap}} )</td>
<td>Radius of capillary tube</td>
<td>&lt;&gt;</td>
<td>m</td>
</tr>
<tr>
<td>( \Delta P )</td>
<td>Change in pressure</td>
<td>&lt;&gt;</td>
<td>kg/m-s²</td>
</tr>
<tr>
<td>( \Delta h )</td>
<td>Change in height of fluid</td>
<td>&lt;&gt;</td>
<td>m</td>
</tr>
</tbody>
</table>

WORKSHEET A

Be sure to use the preferred units listed in the table above.

Segment A:

<table>
<thead>
<tr>
<th>Capillary A</th>
<th>Inside Diameter = ____ m</th>
<th>Capillary B</th>
<th>Inside Diameter = ____ m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>( \Delta h: )</td>
<td>Trial 1</td>
<td>( \Delta h: )</td>
</tr>
<tr>
<td></td>
<td>( \Delta P: )</td>
<td>Trial 2</td>
<td>( \Delta h: )</td>
</tr>
<tr>
<td>Trial 2</td>
<td>( \Delta h: )</td>
<td>Trial 2</td>
<td>( \Delta h: )</td>
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<tr>
<td>Trial 3</td>
<td>( \Delta h: )</td>
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<td>( \Delta h: )</td>
</tr>
<tr>
<td></td>
<td>( \Delta P: )</td>
<td></td>
<td>( \Delta P: )</td>
</tr>
</tbody>
</table>
Segment B: GENERIC CHIP FLUID DELIVERY TRIALS

For this lab segment, it is suggested that, assuming a team of four:

- One teammate pumps with the syringe
- Another oversees and makes sure the fluid stops at the proper points
- Another notes observations (should be many issues to consider)
- The fourth can clean, fetch fluids, help with miscellaneous tasks, etc.

1. Clean the chip and chip holder assembly using the ultrasonic cleaner, as described in Supplement 2. Align and reassemble the components properly as described below:

2. Follow the cleaning instructions in Supplement 2 (located after the Lab 2 procedure) before proceeding to the next step.

3. Verify that the chip and chipholder are clean using the 5x magnifier and light box.

THE REMAINING STEPS REQUIRE PATIENCE AND DILIGENCE AND ARE CRITICAL AS THEY INVOLVE THE ALIGNMENT OF ALL THE CHIP ASSEMBLY PARTS AND ACCESS POINTS!!

4. Place a chip holder base on the printout created earlier of the generic chip,

5. Place a drop of water in the center of the chip holder base, design-side up and lined up with the design on the printout. The drop of water is to ensure that there is no air between the bottom of the chip and the chip holder. Be sure there are no air bubbles between the chip holder base and acrylic chip bottom. Be sure that the holes line up with both the wells and the chip holder holes drawn on the outline.

PRECISE ALIGNMENT OF THE DETECTION WELL AND STAGING WELLS IS IMPERATIVE!

6. Now do the same with your PDMS lid, once again being sure to keep everything aligned, especially the staging wells and access holes on the PDMS lid, acrylic chip, and chipholder. When placing the PDMS lid on the acrylic chip base, make sure you roll the lid onto the acrylic surface to avoid air bubbles.

7. Place the acrylic chip holder top over the entire assembly, once again while being wary of bubbles, alignment, and possible debris.

8. Turn the 3 nuts only as much as necessary to hold the top in place and maintain a seal. Be careful not to apply torque beyond the free spinning point, or your chip may not perform properly. This means spinning the loose nuts until they stop, then adding only a slight additional turn, just enough to hold them and the assembly in place and applying only minimal pressure or ALMOST NO PRESSURE to the chipholder and chip. You do not want to compress the acrylic chip at all.

9. When you have finished assembling your chip holder-chip assembly place a syringe with fluid (water or dyed water) directly into an entrance port over a staging well. Another syringe can be placed at the opening on the waste well.
10. Plug the remaining staging well ports with the green tapered tips with the caps placed on them.

11. Start entering dyed water into a staging well with the syringe.

12. Send the water from the staging well to the detection well and then to waste well. Your purpose is to fill detection well fully. Use steady but moderate pressure from the syringe so as not to cause any leaks. Slight suction can be applied with the syringe at the waste well.

13. Use the 5x magnifier and light box to identify dirt, debris, damage to the PDMS, etc. and note the potential effects on chip performance.

Figure 2. Acrylic chip, PDMS lid, and chip holder aligned and assembled over design printout.

14. You may repeat the last three steps if the chip features do not appear clean.

15. Practice the following sequence, alternating staging wells with different (clear or dyed) DI water:

   a. Send a sample of dyed water from a staging well to the detection well, using a syringe. Be sure to completely fill the detection well. Look out for air bubbles in the detection well and leaks from the channels. See Supplement I to correct these problems.

   b. Rinse out the affected features with clear water. Repeat with another well and/or different technique and procedure variations. Be mindful of what works and what does not work. Be mindful of applying only as much pressure as necessary to move the fluid through the chip. Make notes on what works and what does not.

   c. Diligently record techniques/procedures and observations of results (e.g., “Well1 – pump with agent, stop, check for bubbles/leaks, well1 – flush with DI water, well2 pump…” , “Worked well except for flushing phase from well2”, “We see issues with… …and potential success with…”, etc.).