Home lab: sedimentation, capillary action and laminar flow

Introduction and preparations

The purpose of this lab exercise is to study microfluidic phenomena you can find at home in your everyday life, such as sedimentation, capillary action and laminar flow. You do the exercise on your own or in pairs. You are expected to do the lab exercise during course week 1 and summarize your methods and results in an individual movie handed in latest course week 2 (see reporting below).

In the tasks below we have left some room for you to solve the tasks using your creativity. You are welcome to discuss how to solve the tasks with your peers if you want to, e.g. in the Home Lab Canvas discussion thread. If you have questions, you can also email us or discuss with us when we have class. Remember to take pictures and video clips during your experiments that you can use in your recording.

Preparations

1. Pick up dry yeast at one of the lectures if you don't want to use your own. Alternatively, bring a glass marble and potato starch.
2. Make sure that you have passed the Plagiarism Quiz in Canvas with full score.
3. Read page 99-101 about laminar flow and 112-113 about surface tension in *Introduction to BioMEMS* by Albert Folch. The course book is available at the Study Center and online from the University Library.

Task 1: Sedimentation

In this task you will study sedimentation and you can choose between two tasks (or do both). One option is to measure the sedimentation of dry yeast in water to estimate the size of yeast cells. Option 2 is to measure the viscosity of slime through the sedimentation of a glass marble. Dry yeast, marbles and potato starch will be distributed during the lectures.

Yeast (option 1):

1. Mix dry yeast well with water in e.g. a glass. Only use a tiny amount of yeast at first and then increase the concentration by adding more if it is necessary to see where the yeast is. You want the concentration to be low enough so you can see light through the glass but still you want to be able to clearly observe the mist of yeast as it sediments. If you are unsure, you can run several concentrations in parallel.
2. Image and measure how far the yeast has sedimented at regular time intervals by looking at the division between the clear fluid and the sedimenting yeast. This will take a few hours so you can do other experiments or studies in parallel. Here is a simple tool to measure distances in images (https://eleif.net/photomeasure).
3. Plot sedimentation distance (the distance from the water surface to the top of the sedimenting yeast fraction) as a function of time.
4. Make a fit to the datapoints and calculate the sedimentation velocity from the slope. The density of the yeast cells is approximately 1.11 g/mL.

5. Estimate the size of the yeast cells from their sedimentation velocity (see lecture on laminar flow). Does this size agree with what you can find by searching online?
6. Things to address in the presentation:
   a. Describe very briefly the experiment.
   b. Plot your data.
   c. What forces are in balance?
   d. Discuss some of the assumptions that the model is based on.
   e. Does your result agree with what was expected? If not, why could that be?

Slime (option 2):

1. Figure out an expression for the sedimentation of a sphere and how this can be useful in this task (see for instance lecture slides on **Viscosity and laminar flow**).
2. Mix 2 tablespoons (30 mL) of potato starch in 4 dl of water and bring to a boil. Feel free to add some food color if you like. Let it cool to room temperature. Your task is to measure the viscosity of this slime by studying the sedimentation of a marble through the slime.
3. Image and measure how long time it takes for the marble to sediment in the slime. If you take a video or photos at regular time points you can figure out if it is accelerating or not.
4. Plot sedimentation distance (the distance from the water surface to the marble as a function of time.
5. Make a fit to the datapoints and calculate the sedimentation velocity from the slope. Calculate the density of the glass marble by weighing and measuring it (can be done during a lecture).
6. The density of the slime can vary (https://www.youtube.com/shorts/5HNN0SwdRJI?feature=share) but how important is the exact value for the accuracy of the results? Measure it or estimate it.
7. Estimate the viscosity of the slime from the sedimentation velocity of the marble.
8. Things to address in the presentation:
   a. Describe very briefly the experiment.
   b. Plot your data.
   c. What forces are in balance?
   d. Discuss some of the assumptions that the model is based on.
   e. Does your result agree with what was expected? If not, why could that be?

Task 2: Capillary action

In this task you will study capillary action in paper and other materials.

1. Choose at least three materials to study (e.g. printer paper, newspaper paper, toilet paper, Wettex, a piece of cloth, a thread…).
2. If necessary, cut pieces of a suitable size.
3. Place the material vertically and dip one end in water or place water in a spot. Image and measure the distance (L) that the water is pulled into the material over time (t). Replenish the water reservoir if it runs out.

4. If you want to you can compare how this works if the material is horizontal or vertical, if the material is in contact with the surface below or not, or what happens if you add food coloring.
5. Plot *L* as a function of *t*.
6. Things to address in the presentation:
    a. Describe very briefly the experiment.
    b. Show the plotted data.
    c. Does the travelled distance of the water-air interface increase linearly with time?
    d. If not, can you figure out why by discussing the forces that are responsible for pulling and resisting the flow? Does any of the forces depend on *L*?

Task 3: Laminar and turbulent flow

In this task you will study laminar and turbulent flow in a tap.

1. Find a water tap where the flow transitions from laminar to turbulent when you open it.
2. Find a flow rate where the flow is clearly laminar, i.e. a very thin stream that appears completely steady and clear over time.
3. Image the stream.
4. Measure the width of the stream at different distances from the tap.
5. Measure the volumetric flow rate.
6. Find a flow rate where the flow is turbulent (but still without interspersed air or bubbles) and repeat 3-5.
7. Find a flow rate at the transition between laminar and turbulent, if possible where the flow transitions from laminar to turbulent as it falls, and repeat 3-5.
8. Calculate the Reynolds number at the different distances from the tap for your measured flow rates.
9. Things to address in the presentation:
    a. Describe very briefly the experiment.
    b. Show the data.
    c. What forces does the Reynolds number compare?
    d. How does the Reynolds number change along the stream, and why? I.e. what parameters change and how to they contribute to the Reynolds number?
    e. Do the Reynolds numbers you calculate agree with what you would expect? Why or why not?

Reporting

After the lab exercise, you summarize your work individually in a maximum 7-minute long video. Video clips, photos, illustrations and plots necessary to understand your experiments should be included in the video. By formulating in your own words what you have observed, you will better internalize what you have learnt. If you have performed the lab together, name you lab mate in the movie, but still make one video each. To know that it is you that have produced the video, your face needs to be visible live somewhere in the movie.

One simple way to produce a video is to put all material that you intend to show in a PowerPoint slideshow. Then you start a Zoom meeting with yourself with share screen on. When you are ready to start, you press record and make a voice-over as you go through the slides. If you have video turned on, your webcam video will be visible in the top corner of the produced video.

The video clip is due one week after the assignment was given and should be submitted through the Home Lab assignment in Canvas.