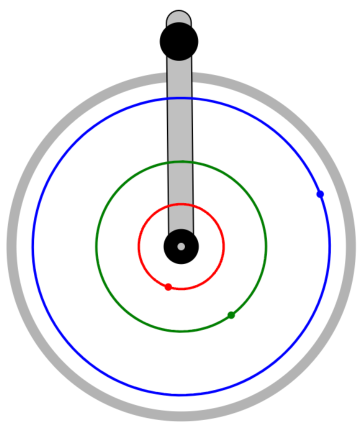
Worksheet: Viscous flow around a rotating cylindrical rod

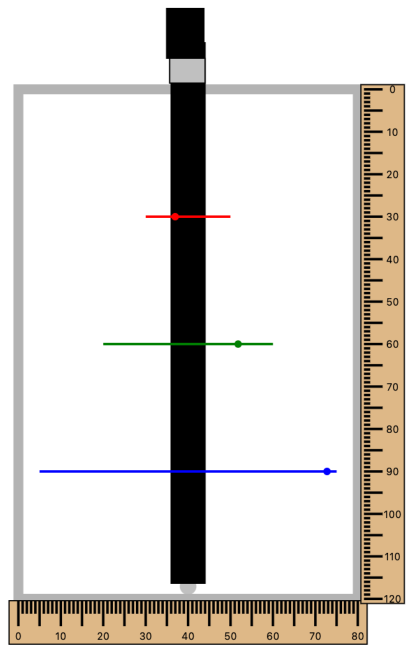
Name(s):____

Fill in all sections – These are today's notes

Student learning objectives
1. Measure velocity profile at low Reynolds number around a cylindrical rod
2. Understand how velocity profile decays radially away from the rod
3. Understand how velocity profile varies vertically for a long rod
4. Derive the velocity profile for flow around a rotating rod
5. Compare the measured velocity with experiments

Dimensions and details of the experiment





The experiment consists of a cylindrical rod immsersed in glycerol that can be rotated by the handle towards the end. The three dots represent three inks that we will stretch as we rotate the rod. Their angular position will be tracked with time to measure the rotational velocity of each point. The goal of this experiment is to understand the velocity profile and compare with the prediction.

Before starting the experiment.

1. If you rotate the the rod clockwise, will the the points move clockwise as well? Explain your reasoning.

2. If the rod is rotated by 360 degrees, how much will the red point rotate (= 360 degree, < 360 degree, > 360 degree). Explain your reasoning.

3. If the rod is rotated by 360 degrees, how much will the blue point rotate (equal to the rod, equal to the red point, less than the red point). Explain your reasoning.

4. Will gravity have any effect of the velocity profile? Explain your reasoning.

5. How many full rotations (i.e., in multiple of 360 degree rotations) of the rod will it take to make one full rotation of the blue point. Guess the answer and explain your reasoning.

6. If your rotate the rod three times and rotate it in the opposite direction three times such that it is back in its original location, what do you think will happen to the three points?

During the experiment.

1. Measure the diameter of the cylindrical rod and the radial distance of the points away from the center of the rod. Report the values.

2. Measure the height the points from the top of the cylinder. Report the values.

3. Now, rotate the cylinder slowly clockwise fully 2 times (one full turn is 360 degrees); try to be as uniform as possible. Make sure that you are rotating the cylinder slowly enough such that each turn takes at least a minute. Start a stopwatch and report time versus angular position of all the 3 points and the rod in a plot below. Make sure you are taking at least 10 points in each rotation.

4. Now, rotate the cylinder slowly counterclockwise fully 2 times such that you are back in the original position. What do you observe about the position of the points vis-à-vis compared to the original position?

After the experiment.

1. You are given that $v_\theta = \frac{\omega_{rod} R_{rod}^2}{r}$, where r is the radial distance away from the center, ω_{rod} is angular velocity of the rod, and R_{rod} is the radius of the rod. How will you show that your experiment alignts with this prediction? Suggest a plot to verify whether this is observed. (*Hint:* $v_\theta = r\frac{d\theta}{dt}$). If you are unable to suggest a plot, consider plotting $\Delta\theta_{point} r_{point}^2 / R_{rod}$ versus $\Delta\theta_{rod}$, where $\Delta\theta_{point}$ and $\Delta\theta_{rod}$ represent the difference in angular positions from the initial position for the points and rod, respectively.

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2. You are given the density of glycerol 1,260 kg/m^3 and viscosity of the glycerol if 1,700 Pa·s. Define a Reynolds number for the experiment and calculate its value (*hint: calculate the angular velocity of the rod by taking the time it took to do one full turn*)

3. Why does gravity not impact the velocity profile? Is the pressure different at each point? If so, why does it not create a flow?