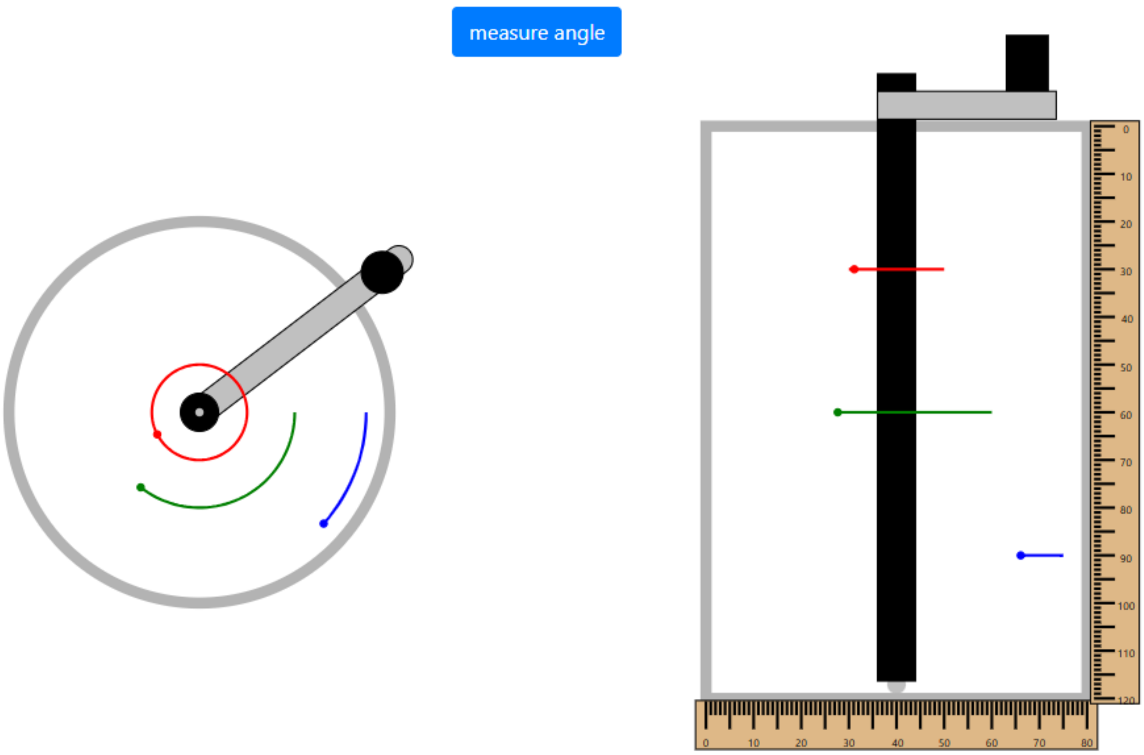
Name(s):____

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 predictions.

Dimensions and details of the experiment



The experiment consists of a cylindrical rod immersed in glycerol. The rod can be rotated by the handle on top of the cylinder. The three dots represent three inks that will stretch as the rod rotates. Their angular positions 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 prediction.

Before starting the experiment.

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

2. If you rotate the rod by 360 degrees, how much will the red point rotate (less than, equal to, or greater than 360 degrees)? Explain your reasoning.

3. If you rotate the rod by 360 degrees, how much will the blue point rotate (ess than, equal to, or greater than the red point)? Explain your reasoning.

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

5. How many full rotations (i.e., in multiples 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 you rotate the rod three full rotations and rotate it in the opposite direction three full rotations 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. Record the values.

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

3. Rotate the cylinder slowly clockwise two complete rotations (one full turn is 360 degrees); try to be as uniform as possible. Rotate the cylinder slowly enough so each full 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 take at least 10 points in each rotation.

	Angular position			
Time (s)	red	green	blue	rod

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 compared to their original positions?

Analysist

1. Given that

$$v_\theta = \frac{\omega_{rod} R_{rod}^2}{r}$$

where v_θ is component of velocity in the θ direction

ω_{rod} is angular velocity of the rod

R_{rod} is the radius of the rod

r is the radial distance away from the center

suggest a plot to verify that your experiment aligns with this prediction. (*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.

2. The density of glycerol is 1,260 kg/m^3 and its viscosity is 1,700 Pa·s. Define a Reynolds number for the experiment and calculate its value (*hint: calculate the angular velocity of the rod from 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?