We can use flow through a tube to measure viscosity:

**Hagen-Poiseuille Equation:**

- **without gravity**
  \[ Q = \frac{\pi (p_0 - p_L) R^4}{8 \mu L} \]
- **with gravity**
  \[ Q = \frac{\pi (p_0 - p_L + \rho g L \cos \theta) R^4}{8 \mu L} \]

**Assumptions:**
- Steady state
- Incompressible
- Newtonian
- No end effects

Cannon-Fenske Viscometer

- Gravity driven
- Results in *kinematic viscosity*
- Requires loading a fixed volume that is specific to the supplied calibrations

\[ v = \frac{\mu}{\rho} \]

Neglect \( \Delta p \), solve for \( v \):

\[ v = \frac{\mu}{\rho} = \frac{\text{correction factor}}{(\pi R^4 g \cos \beta)} \frac{\Delta t}{8 \Delta V} \]

*Kinematic Viscosity, \( v \)***

\[ v = \alpha \Delta t \]

(For complete analysis, see Morrison, *An Introduction to Fluid Mechanics*, Example 7.4, p508)
**Ubbeholde Viscometer**

- Gravity driven
- Results in kinematic viscosity
- *Vented exit allows variable volumes to be charged*
- *Design eliminates Δp*

\[
\nu = \frac{\mu}{\rho}
\]

**Loading a Cannon-Fenske Viscometer**

- Accurate calibration requires using the calibrated volume
- Fill to top mark

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See class website for detailed instructions on operating the Cannon-Fenske Routine Viscometers.

Instructions for the use of the Cannon-Fenske Routine Viscometer
Cannon-Runhoff Company
Modified by T. A. Morrison 13 September 1997

1. Obtain a sample, a viscometer of appropriate size, and approximately 10 cc of sample (state volume).
2. Mount the viscometer to the viscometer holder (or any other holder that allows the holder to be adjusted vertically) in the test equipment. If the holder has an adjustable viscometer, make sure the holder is adjusted to 45° from the horizontal plane of the holder.
3. Fill the sample to the sample to the top of the sample cup.
4. Turn the holder so that the viscometer can be observed from above. If the holder has an adjustable viscometer, make sure the holder is adjusted to 45° from the horizontal plane of the holder.
5. Turn the holder so that the viscometer can be observed from above. If the holder has an adjustable viscometer, make sure the holder is adjusted to 45° from the horizontal plane of the holder.
6. Turn the holder so that the viscometer can be observed from above. If the holder has an adjustable viscometer, make sure the holder is adjusted to 45° from the horizontal plane of the holder.
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9. Turn the holder so that the viscometer can be observed from above. If the holder has an adjustable viscometer, make sure the holder is adjusted to 45° from the horizontal plane of the holder.

Each group takes the viscosity of two solutions at three temperatures.

Data are shared with all lab classmates (Google Forms)

See table for assignments (also given in the lab handout)

<table>
<thead>
<tr>
<th>Station</th>
<th>Solutions to Measure (wt% sugar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10.0</td>
</tr>
<tr>
<td>4</td>
<td>30.0</td>
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<tr>
<td>6</td>
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<td>8</td>
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<tr>
<td>9</td>
<td>50.0</td>
</tr>
<tr>
<td>10</td>
<td>10.0</td>
</tr>
</tbody>
</table>
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Lab: Measure Fluid Viscosity

- Measure densities, efflux times of sugar solutions at various concentrations, temperatures
- Calculate viscosities; enter into Google Form
- Determine experimental uncertainty
- Determine best-fit line at three temperatures; plot on one graph; compare to literature
- Identify concentration of mystery solution (with uncertainty)

Class: In your submissions to the Google Form:

- Do not write 30%; just write 30
- Do do not write the units in your entries; it’s going directly to Excel.
- If you want to use scientific notation, please write 3.14e3 for 3140 (do not write 3.14*10^3). It’s going directly to Excel.
Pre-lab assignment (due Monday):

• Obtain the literature values of solution densities and viscosities before lab; this must be in your notebook for Monday’s prelab check.
• Please do the pre-lab—this is to enhance your laboratory experience
• Note the references where you found your values.
• See instructions for complete prelab assignment.