LABORATORY 1 - FLUID PROPERTIES

I. Objective

The fluid properties investigated in this laboratory are density (**ρ**), specific gravity (**SG**), dynamic and kinematic viscosity (**η** and **υ**) and surface tension (**σ**). From a hydraulic engineering standpoint, density and viscosity are the most important; surface tension is important in subsurface contaminant transport. The objective here is to demonstrate the measurement of these **primary fluid properties** and to show you how **derived physical properties** behave as a function of primary physical properties.

II. Equipment

Pycnometer, graduated cylinder, hydrometer, electronic balance, Cannon-Fenske viscometer, pipet bulb, stand and clamp, stopwatch, capillary rise surface tensiometer and tape measure. The fluids we will study are: water, oil, a mystery fluid and rubbing alcohol (note that rubbing alcohol is a solution consisting of 91% isopropyl alcohol and 9% water).

All measurements will be repeated for *each fluid*. A total volume of 200 ml of each fluid will be required for each group.

Each group will measure all four parameters for each fluid. Depending on lab session size and time available, there will be a total of up to **4 density and 4 specific gravity measurements per laboratory** (*4* fluids); **4 kinematic viscosity measurements** (*4* fluids, possibly **only 2 per laboratory session** due to time constraints); at least **4 σ measurements** (*4* fluids, **potentially less than four per laboratory session** due to time constraints). You will **combine the data from all three laboratory sessions in your analysis** (available on the course webpage).

In your report you will tabulate the mean ± standard deviation for *each parameter* for *each fluid*. For parameters requiring a derived unit (such as dynamic viscosity), use the mean value for *all* density measurements.

III. Procedures (four total)

1) Pycnometric density measurement (ρ)

1. Measure the mass (g) of the dry bottle of known volume (ml) and stopper using the electronic balance (*be sure to record the reading!)* Note the matching numbers ground in both the bottle and stopper.
2. Fill the bottle to just above the white line and replace the stopper.
3. Remove any residual fluid. Measure the mass of the bottle, stopper, and fluid (g).
4. Subtract the first measurement from the second to obtain the fluid mass.
5. Divide the fluid mass by the volume of the pycnometer and convert to ρ (**kg/m^3**).

2) Hydrometric Specific Gravity measurement (SG)

1. Fill the graduated cylinder approximately ~¾ full with the liquid.
2. Using the appropriate hydrometer specific gravity (SG) reading for the density of the liquid (*Note, be careful with the hydrometer; DO NOT drop it in the fluid*), record the SG and measure the liquid temperature. Compute **ρ** (**kg/m^3**) from the density of water from the pycnometer reading.

3) Cannon-Fenske viscometer (η and υ) (NOTE: Possibly as few as two measurements per lab session!)

Please be careful handling the viscometers!

1. Fill the larger opening of the viscometer with ~6.2 ml of liquid. **Lab 1: rubbing alcohol and mystery fluid; Lab 2: water and oil; Lab 3: duplicates (time depending).**
2. Apply suction to the smaller opening using a pipet bulb until the liquid level is above the upper red line.
3. Clamp the viscometer in a vertical upright position. Remove the pipet bulb.
4. Start the timer when the liquid level reaches the upper red line and stop the timer when the liquid level reaches the lower red line.
5. Multiply the elapsed ***efflux time t*** (**s**) by the calibration constant (**$\upsilon = Ct$**) for your viscometer (be sure the codes match) to determine the kinematic viscosity as (**mm^2/s** or **centistokes, cSt**). Use the average calibration constant for the viscometer you are using and convert to the SI **m^2/s**. *Note:* the full equation was given in class (*equ. 2-5 in Mott*). All parameters are lumped into the calibration constant except the term $(\boldsymbol{v\ l})^{-1}$ which is the efflux time.
6. Calculate the **η**, the dynamic viscosity {**kg/(m s)**} from the *mean* density for the appropriate solution obtained from the density measurement exercise.

4) Surface Tension against air (σ)

1. Fill the apparatus until the liquid level is above the zero mark and record the level (cm).
2. Apply and release pressure to the spout to force liquid all the way up the capillary tube (repeat if necessary).
3. After allowing the liquid to equilibrate, record the liquid level in cm.
4. Determine the capillary rise by subtracting the first measurement from the second.
5. Repeat this measurement by (repeating step 2) to ensure precision.
6. Calculate **σ**, the surface tension (**dyne/cm**) using the capillary rise equation* using your measured density (**ρ**) and gravitational constant (**g**) and convert to the SI **N/m**.

IV. Report Questions

1. Tabulate **ρ**, **SG**, **η** and **υ**, and **σ** measurements for the various methods. Compare these with reference values and comment on similarities or differences. Also compare the mean ± standard deviation for ρ values to determine whether the two methods give *statistically significant* differences (here significance for one standard deviation is 67%).

2. Record and tabulate the mystery fluid measurements obtained by each group. Based upon ρ, SG, η and υ, and σ, can you identify the fluid?

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* The balance of forces between the *downward* weight (w) of the liquid column in the capillary and the *upward* surface tension force (F_c) acting around the meniscus circumference inside the capillary: $\boldsymbol{w = F_c}$ or $w = \gamma V = \gamma(h\pi r^2) = F_c = \sigma 2\pi r\cos\theta$ at equilibrium. Assuming the contact angle *(θ)* between the meniscus and capillary wall =0; this gives: $\sigma = \frac{\gamma hr}{2}$