Introduction to Chemical and Biological Engineering (CBE 101)

Department of Chemical and Biological Engineering
Colorado State University

Course Packet

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Resources for Lab Groups

Essentials for Successful Group Work

In CBE 101 lab you have to work in groups. Some of you will thrive in this setting; others will feel frustrated, annoyed, or perplexed. **Successful group work requires that conflicts be (1) prevented, (2) identified and (3) resolved.** The next three sections describe these steps.

Preventing Conflicts in Groups
If each member of your group has these seven expectations, you group will avoid most conflicts. This list is what I expect from all of you as individuals and as groups.

1. **Successful group work requires engagement.** Everyone is expected to make contributions to the group. If someone is not contributing the group should encourage that person to engage.

2. **Successful group work requires communication.** Be very clear with your group about how you will communicate, and then always respond in a timely way. If you agree to communicate by email, always reply to your groups' email messages, and don't leave people out. Always share electronic files and data collected during the lab with the entire lab group as soon as possible. This way if the one person who has the data loses it or cannot attend a group meeting, the group can still function.

3. **Successful group work requires planning.** Everyone has different priorities and schedules. Be sensitive to other peoples' priorities. Your evening job is *not* more important than another student's weekend leisure activity. Evenings and weekends are just that – evenings and weekends. As long as people agree to commitments and contributions and follow through with them, there should be no complaints about how other people manage their time. For that agreement to happen, your group needs to plan meetings, contributions, and deadlines.

4. **Successful group work requires flexibility.** Things will never go the way that you think they will. Someone (maybe you) will not meet a deadline. It could be that their contribution was just way more difficult and time-consuming than anyone thought it would be. Ask for help when you need it, and be helpful when you can. Be willing to change your plans if necessary.

5. **Successful group work can be accomplished remotely.** It is ok if one person cannot meet with the rest of the group. That person can still make valuable contributions by performing calculations, writing and editing sections of a report, and sending them to the rest of the group by email.

6. **Successful group work requires extra time.** Do not expect that every group will work efficiently and effectively from the very start. Everyone has a different schedule, level of understanding of the material, writing ability, work temperament, personality, etc. Excellent groups spend some extra time communicating, planning, meeting, and double-checking and editing the contributions of their group mates.

7. **Successful group work will result in a better product than individual work.** Everyone in your group should have the goal of producing a better report than any of you could produce on your own. You should expect that what you will write or calculate will be checked, edited, and improved by others in your group, and that you should spend some time similarly improving what they produce. You should not be offended if others edit what you write, and you should not begrudge the need to spend extra time editing your group members' contributions. These activities are an essential part of group work that will help you become a better student and a better engineer!

Identifying Sources of Conflict

Your group is almost guaranteed to encounter situations that *could* lead to conflict. By considering the following scenarios before (or during and after) they occur to you, your group might avoid conflict.

1. **One or more group members are doing all the work, while one or a few of the others are doing very little. The solution is <u>ENGAGEMENT</u>.** This can happen for a variety of reasons, and is not the way a successful group should function. Non-contributing members might feel uncertain about their ability, uncomfortable asking questions, or simply un-interested in working with a group. The more active members of the group can prevent conflict by communicating that they value the contributions of the less active members. This can sometimes be accomplished by asking questions. "Do you understand this calculation?" "How do you think we should estimate this uncertainty?" "Can you please read what I wrote and suggest some edits?" "Could you double check these calculations – I'm not sure I have this unit conversion right." *Failing to engage only reinforces the behavior of the non-contributing members*.

2. **One group member cannot meet a deadline or join the group at an agreed meeting time. The solution is <u>COMMUNICATION</u>.** This group member might be hesitant to admit that they need help completing something, or that they didn't do a good job managing their time. This attitude is understandable – but the group member should heed item 2 in the first list. The best way to avoid conflict is to tell the group exactly what is going on, and make alternative arrangements. If they remain silent, the rest of the group will likely come to the logical conclusion that the absent or delinquent member doesn't want to contribute or is just being rude and inconsiderate. The group should respond by giving delinquent members the benefit of the doubt – offer to help, expect that the member can still finish the work, be flexible and willing to re-arrange the workload to include this member to the extent possible.

3. **Group members have different priorities. The solution is <u>PLANNING</u>.** Discussing *why* a group can't meet on a particular weekend or weeknight will only lead to the group making subjective judgments about whose activities and schedules are more important (is studying for an exam for another class, taking an extra shift at work, or attending a friend's wedding a legitimate reason to miss a meeting? As a group, you cannot prioritize other people's activities.) As a group, you have to agree to plan around each other's conflicts without trying to manage their time for them. Students should always be present during class, unless they have a conflict due to a University sanctioned event (e.g. NCAA sports teams, etc.). Outside of class students should have several hours per week to dedicate to this class, but those particular hours might not always coincide, so you have to plan and be flexible.

4. **One group member has consistent rude or unhelpful behavior. The solution is <u>COURTESY</u>**. A student who is consistently un-responsive to emails, fails to meet previously agreed obligations, or is otherwise inconsiderate of group members will cause a conflict within a group. The best way to avoid this is to not be that guy! The entire group needs to communicate about this behavior early so that it doesn't lead to extra work for the rest of the group members. They should also communicate concerns to the instructor as soon as they become apparent.

Resolving Conflicts
Despite your best efforts, some conflicts will arise. When that happens, here is what you should do:

1. **Let me know that your group has a problem, and exactly what that problem is.** This should be done as soon as the conflict arises. Email or a visit to my office is best.

2. **Suggest reasonable solutions.** Your ideas about how everyone should get along are probably the best ideas (and might be more agreeable to you than my solution!).

3. **Err on the side of restoring and redeeming successful group work.** You do not absolutely have to work in a group outside of class to be successful in CBE 101. If your group absolutely cannot function, you may be permitted to submit lab reports on your own – but that is rarely the best solution.

4. **Do not allow the behavior of one group member to cause a lot of anxiety or extra work for the rest of the lab group.** Recognize that there is a problem and take the steps above to resolve it!

If you let me know that your group has a conflict, this is what you can expect from me:

- I will want to know exactly what the problem is and what steps you have taken to resolve (or perhaps complicate) the situation.
- I will discuss the conflict with all members of the group, and expect you to do the same.
- I will suggest a short-term course of action for the current situation. This might be a redistribution of the immediate workload, a meeting with the entire group, or that some group members work separately.
- I will coach the group on how to relieve the pressures that led to the conflict in the first place. This rarely involves the behavior of a single group member. Usually, even if one group member is causing headaches for everyone else, the group's responses are just as important as the original offenses.
- Groups might be reassigned – especially in the case of 'no-fault' types of conflicts – such as complete incompatibility of the various group members' class and work schedules.
- I will expect that you provide continued feedback on how the conflict is being resolved.

A note on leaving a lab group member's name off of a lab report:
If your group has one or more members who are making no substantial contribution to the group's work, then their name should not be included on the lab report. *Note that this is NOT a solution to a conflict – this is a sign that there is a problem within the group that needs to be addressed.* You should NOT do this if a group member is demonstrating genuine enthusiasm or interest in contributing but is just unhelpful, clumsy, or incompetent. If your group submits a report with one or more names missing, you should also do the following:

1. Notify me that your group is having a problem and what the problem is.
2. Notify the delinquent member (or ask me to do it for you). Don't surprise them on the day that the report is due!
3. Provide that group member with the data your group has collected in the lab, especially if they participated in the lab activity. They will need the data if they choose to write and submit their own lab report.
4. Expect that any present conflict can be resolved so that the group can continue to function well on future work.

Laboratory Report Instructions

All lab reports should conform to the following format.

- Use 8 ½” × 11” page size, single-spaced, 12-point font, 1-inch margins, and consistent typeface.
- Two to three pages of text is a good length for most reports. Use the length you need to communicate everything that you need to say, without adding extra, superfluous text just to fill space. Graders don’t like to read more than they have to!
- Figures and tables should be included as needed, but these do *not* count toward total length.
- Figures and tables should be prepared in a professional manner, preferably using engineering software. Hand-drawn illustrations may be ok in some situations, as long as they are well-prepared. Prepare figures electronically whenever possible. Physical quantities should include units and uncertainties, and only the correct number of significant digits. See pages 8-10 for more information on how to correctly report significant digits and uncertainties.
- All display items (figures, tables, etc.) should be numbered and have a brief caption (placed below the image for figures, including graphs, schemes, and diagrams) or title (placed above, for tables). See your textbook for examples of how to correctly label figures and tables. Display items should be referred to in the text by their number.
- All equations should be prepared professionally (e.g. using Insert → Equation in MS Word) and set on their own line. Define all symbols used, and use consistent notation.
- Include the names of all lab group members that contributed to the experiments and the preparation of the report.
- Everything that you write should be in your own words! Do not copy text from the lab description or others’ lab reports!

See the included examples of excellent and poor lab reports. The entire report (including appendices) should be prepared as a single file and submitted electronically, via Canvas. Supporting files such as MATLAB programs or Excel spreadsheets may also be submitted, but it is *not* ok to submit multiple versions or several files containing different sections of the text!

Writing style tips

Writing a group lab report is a group effort. Each member of the group makes some contributions, and the report might be compiled by one or two people. ***However, every member of the group should read the final report before it is submitted.*** Do not simply cut and paste sections written by different people together and expect to have a good report. Plan on spending some time editing the final version to make it cohesive. If several people write different sections, you may need to add appropriate transitions, move text from one section to another, delete redundant or contradictory statements, and edit for consistent use of wording and notation. ***Writing as a group should be an exercise that improves everyone’s final product, rather than a compilation of errors.*** Do not be offended if a group member suggests re-wording or deleting something that your wrote. The objective should be to produce the best final product. Here is a list of additional things to check when editing:

- Check the spelling and grammar. Use good sentence structure. Eliminate run-on sentences. Make sure that the subject and verb are in agreement, and use parallel constructions effectively.
- Use good paragraph structure. Eliminate single-sentence paragraphs.
- Organize ideas logically within paragraphs and within sections.
- Strive for smooth flow of ideas. Ideas should be introduced and supported, and the transition to the next idea should make sense. Use consistent wording, notation, and voice throughout.
- Check the tone. It should be professional but not stilted.
- Confirm correct units and significant figures on all physical quantities.
- Re-read the lab instructions to be sure that you have answered all of the questions.

Suggested outline

I. Introduction (or Overview, or Objective)

In one or two paragraphs, describe the objective/goal of the experiment. Concisely describe the physical principle investigated.

II. Materials and Equipment (or Experimental Apparatus)

In one or two paragraphs, briefly describe the materials and equipment or apparatus that were used. Explain any special preparations that were required.

III. Procedure (may be combined with the previous section for simple experiments, but for complex or multi-step procedures this might be a separate section)

In your own words, briefly summarize the steps taken during the experiment. Provide enough detail so that someone who is unfamiliar with the experiment would understand what you did and why you did it. Be sure to describe any departures from the standard procedure.

IV. Results and Discussion

Report your results and observations. For quantitative experiments, be sure to provide the raw data and the equations used in your calculations, as well as the final results. If original data are extensive, they could be included as an appendix and referred to in this section. Tables, graphs, and figures should be used effectively to highlight key findings and to summarize your results.

Discuss what you concluded from the results obtained and the observations made. Explain the reason(s) for any discrepancies in your results, even if it is necessary for you to make educated guesses. Be sure to answer any questions posed in the lab guide for the experiment. Include discussion of possible sources of error and uncertainty in experimental measurements. Separate "Results" and "Discussion" sections might be appropriate.

V. Conclusion

In a single paragraph, briefly summarize the key results and the main points from your discussion in section IV. This section might be missing if separate "Results" and "Discussion" sections are used. In this case, the last paragraph of the "Discussion" should be the Conclusion.

VI. References

A list of references (if any) cited in the body of the report.

VII. Appendices

Include data and notes collected during the lab, and hand-written example calculations. This is particularly important to demonstrate correct use of units. Since these are your lab notes, it is ok to cross out a mistake and correct it. Do not erase!

Example Lab Reports

CBE 101: Introduction to Chemical and Biological Engineering
Spring 2019
Lab 10 – U-Tube Manometers

In this laboratory assignment you will explore the concept of static fluid pressure, by measuring the pressure of a column of fluid. You will compare the pressures of various fluid columns to the theoretical pressures that these columns should generate. The columns of fluid will be created by filling a reservoir with a volume of fluid. The pressure will be measured using a U-tube manometer.

Principles:
The pressure generated by a column of fluid at rest is called the hydrostatic pressure. Recall that a pressure, P, can be defined as a force, F, acting on an area, A.

$$P = \frac{F}{A} \tag{25}$$

In the case of the hydrostatic pressure of a column of liquid, the force is the force of gravity acting on the mass of liquid, and the area is the area cross-section of the column. The force, F, in equation 1 can be written as:

$$F = gm = g\rho hA \tag{26}$$

Where g is the gravitational acceleration, ρ is the fluid density, and h is the distance from the top of the column to the point where the pressure is being measured. Inserting the right-hand side of equation 26 into equation 25 yields:

$$P = \rho gh \tag{27}$$

Thus, the difference in pressure, $\Delta P = (P_2 - P_1)$, between two heights z_2 and z_1 can be written:

$$\Delta P = \rho g(-\Delta z) \tag{28}$$

Manometer operation:
A U-tube manometer is illustrated in Figure 10.1. A U-shaped tube is filled with a fluid, and the difference in the height of the fluid on either side of the "U" is used to determine the difference in fluid pressure on either side of the tops of the tubes.

Experiments:
The apparatus for this lab is illustrated in Figure 10.2. You have three cylindrical graduated vessels of different diameters (2, 3, and 5 cm) and three fluids of different densities (water, 50 % 2-propanol in water, and 50 % sucrose in water). Each vessel is equipped with a mercury-containing U-tube manometer that measures the pressure at the bottom of the column relative to the atmosphere.

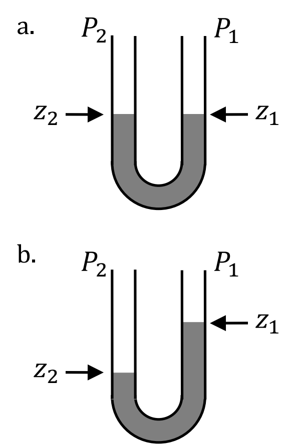

Figure 10.1. A U-tube manometer with $P_1 = P_2$ (a.), and with $P_1 < P_2$ (b.).

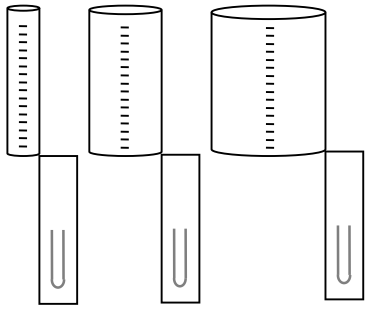

Figure 10.2. Apparatus for this lab: three graduated cylinders of different diameters, each equipped with a mercury-filled U-tube manometer that measures the pressure at the bottom of the cylinder.

Data collection and analysis:

Use the smallest cylinder to measure the pressure of three different columns of water of different heights. You may use the common pressure units of mmHg (millimeters of mercury) since this is the natural pressure units for a mercury-filled manometer. Verify that the apparatus is properly calibrated. (Hint: you can use equation 28 to calculate both the pressure of a column of liquid water of known height and the pressure reading of the manometer. The density of liquid mercury is 13.534 g cm^{-3}. And the density of water is 1 g cm^{-3}.)

Once you have verified that the smallest cylinder is properly calibrated, repeat the experiment with the other three cylinders. Does the diameter of the cylinder affect the measured pressure? Why or why not?

Now use one or more of your cylinders to measure the density of the other two liquids (50 % 2-propanol in water, and 50 % sucrose in water).

Caution: Mercury is a hazardous material. The U-tube manometers contain mercury. While the manometers are designed to be safe to handle, you should be careful not to break them. If mercury is accidentally released, do not touch it or attempt to clean it. Let the lab assistant know immediately. The lab should be evacuated and the CSU Environmental Health and Services office (491-6745) should be notified so that properly trained professionals can clean up the mercury spill.

Lab 10
CBE 103
Group 51
Ima Student
Mia Smarts
Allan A. Day

A U-tube manometer is a device for measuring pressure, which is based on equation 28. In fact, equation 28 is sometimes referred to as “the manometer equation.” We used a manometer to measure the pressure of a column of three different liquids, using three different columns. We also measured the pressures for various heights of the liquids to find out how the density changes with pressure or column height. Each column measured the correct pressure for water even though they are different diameters. The area for a circle is $\pi D^2/4$. So, when you compute the area for each cylinder, you get a different number. But equation 28 doesn’t have the area or the diameter in it so it doesn’t matter. We measured the density of the other two liquids. They are:
Propanol + water = - 0.9 g/cm^3
Sucrose + water = 1.2 g/cm^3

The densities of the mixtures are different because propanol is a liquid, but sucrose is a solid, so when you mix them with water, propanol makes the liquid density go down and sucrose makes the liquid density go up.

Lab 10, CBE 101
Group 61 (Ike Newton, Joey Gibbs, and Mary Currie)

Hydrostatic pressures and manometers

Objective

The objective of this lab is to use U-tube manometers to measure the hydrostatic pressure of columns of three different fluids. The hydrostatic pressure is the pressure caused by the weight of a stationary column of a fluid. The hydrostatic pressure depends upon the height of the fluid column and the fluid density according to the manometer equation:

$$\Delta P = g\rho(-\Delta z)$$

This principle of hydrostatic pressure can be used to measure unknown pressures, if a fluid of known density is used. This is the principle of a U-tube manometer. A U-tube manometer is a device that measures a pressure difference by the change in the height of a column of a liquid of known density. A common fluid used in manometers is mercury, thus pressure is sometimes measured in "millimeters of mercury" (mmHg), which has dimensions of *pressure*, not *length*.

Apparatus and Procedure

Three columns of different diameters were provided. The columns are each connected to a U-tube manometer so that the pressure at the bottom can be measured, when the columns contain a fluid. The columns are also marked with graduations so that the height of the liquid inside the column can be easily measured. The first step is to ensure that the columns and manometers are properly calibrated. To do this, we filled the smallest column with water to three different heights and measured the hydrostatic pressure at each height. Then the density of water could be computed. Since we know the density of water, if we got a correct result, we knew that the manometer and cylinder were properly calibrated. Next we performed the same procedure with the other two cylinders, to examine how the results might change when the cylinder diameter was changed. Once we had verified that the pressure was independent of cylinder diameter, we used the smallest cylinder to measure the unknown densities of two liquid mixtures (50 % 2-propanol in water and 50 % sucrose in water). To measure the density, the pressure of a known height of each fluid was measured, and the manometer equation was re-arranged to obtain the density:

$$\rho = \frac{\Delta P}{g(-\Delta z)}$$

Even though only one measurement was necessary to obtain the density for each liquid, we actually made three measurements for each liquid at different column heights.

Results

The manometer readings at different water heights for each of the three cylinders are shown in table 1. A copy of our data table that we used to collect these data and example calculations are also attached. We noted that the pressure readings corresponding to each height were approximately the same for each cylinder, which means that the pressure does not depend on the diameter of the cylinder. The density of water was computed from the equation above for each manometer reading. We obtained densities for water very close to 1 g/cm^3 for all of the calibration experiments, indicating that manometers and cylinders were properly calibrated.

Table 1. Manometer readings and computed water density for each cylinder.

	Small Cylinder		Medium Cylinder		Large Cylinder	
Water column height (cm)	Manometer reading (mmHg)	Computed water density (g/cm^3)	Manometer reading (mmHg)	Computed water density (g/cm^3)	Manometer reading (mmHg)	Computed water density (g/cm^3)
10	*7.5*	*1.02*	*7.5*	*1.02*	*7*	*0.95*
20	*14.5*	*0.986*	*15*	*1.02*	*14.5*	*0.986*
30	*22*	*0.998*	*22*	*0.998*	*22*	*0.998*

Next we measured the densities of the other two liquids. For this experiment, we used only the smallest cylinder. Our data for these experiments are shown in Table 2. Our data sheets and example calculations are also attached

Table 2. Manometer readings and computed densities for solutions with unknown densities.

	50 % 2-propanol in water		50 % sucrose in water	
Fluid column height (cm)	Manometer reading (mmHg)	Computed fluid density (g/cm^3)	Manometer reading (mmHg)	Computed fluid density (g/cm^3)
10	*6.5*	*0.884*	*9*	*1.22*
20	*13*	*0.884*	*18*	*1.22*
30	*20*	*0.907*	*27.5*	*1.22*

Discussion

For the second part of the experiment, the pressure should not depend upon the diameter of the cylinder. The pressure is caused by the weight of the liquid column. There is more liquid in a larger diameter column, but the force is also distributed over a larger area. So increasing the mass of the liquid increases the pressure, but increasing the area over which the force is distributed decreases the pressure, so the pressure in the manometer equation does not depend upon the diameter of the cylinder. (The diameter cancels out.)

Before doing the third part of the experiment, we did not realize that only a single measurement was necessary to determine the density of each liquid. We performed three measurements for each liquid. However, since we had multiple measurements, we could compare them and see that our data for each measurement were fairly close. (The error on the density was < 5 %.) The error that we did observe probably comes from trying to measure the pressure precisely. The manometer has increments of 1 mm marked on it, but some of the measurements were between mm markings so we estimated, for example 6.5 mmHg for the 10-cm column of 2-propanol solution.

The manometer equation predicts that the pressure should be a linear function of the height of the column, so we plotted the data in Table 2, to see if they are straight lines with intercepts of 0. This plot is shown in figure 1, at the right.

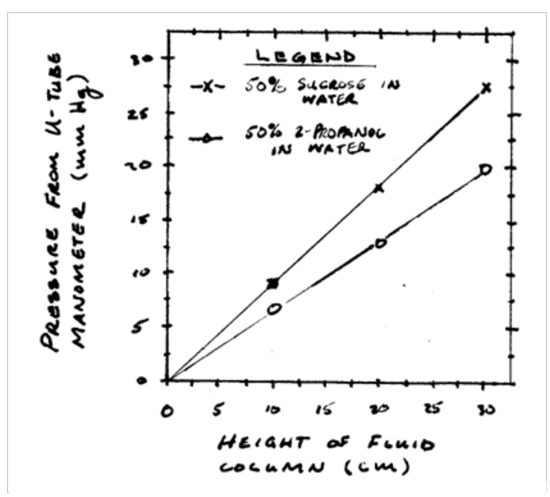

Figure 1. Pressure versus fluid column height showing the linear relationship for two fluids.

We tried to look up the density of a 50 % 2-propanol solution, but we were not able to find it from a reliable source. We did find the density of 2-propanol in a chemical engineering textbook.[1] It was reported to be 0.785 g/cm^3. Our measurements indicate that the 50 % 2-propanol solution in water has a density about half-way between the density of pure 2-propanol and the density of pure water (1 g/cm^3). The density of sucrose solutions is reported in the CRC Handbook of Chemistry and Physics.[2] A 50 % aqueous sucrose solution should have a density of 1.2295 g/cm^3, according to this reference. Thus, our measured density for the 2-propanol solution is reasonable, and our measured density for the sucrose solution is very close to the accepted value.

Our team noted that in this lab we used the manometer equation to measure pressure (when the height and density of the fluid were known) and to measure density (when the height and the pressure were known). We thought that it might also be possible to measure an unknown height of a fluid (if the pressure and density were known). It is apparent that the manometer equation and the concept of hydrostatic pressure are very important, having applications in a variety of chemical and biological engineering problems. They could be used at the design stage to ensure that a vessel is designed to withstand the pressure that it will be subjected to during operation. They could be used in a production setting to measure the pressure in a fluid or process. And they could be used in an analytical setting to measure the density of an unknown fluid.

One of our group members suggested that the manometer equations looks a lot like the Bernoulli equation, with the kinetic energy term set to 0 and the whole equation multiplied by the density. Since the Bernoulli equation comes from the total energy balance, we think that the manometer equation might also be related to the physical law of conservation of energy. But another group member realized that the manometer equation doesn't have any energy terms in it. So as a group, we are not sure whether they are related. Energy is related to forces (force x distance) and pressures (pressure x volume). Potential energy is also related to g and height (mgz). It does seem that all of the terms in the manometer equation can be related to energy. We will ask the instructor whether the manometer equation can be derived from the total energy balance.

[1] R. M. Felder and R. W. Rousseau, *Elementary Principles of Chemical Processes, 2nd Ed.* New York: John Wiley & Sons., 1986.

[2] *CRC Handbook of Chemistry and Physics, 88th Edition (Internet Version),* David R. Lide, ed. Boca Raton: CRC Press/Taylor and Francis, 2008. Accessed through the Colorado State University Library catalog website at *http://catalog.library.colostate.edu*, on Oct. 21, 2008.

WATER COLUMN HEIGHT (cm)	READING FROM MANOMETER (mm Hg) SMALL CYLINDER	MEDIUM CYLINDER	LARGE CYLINDER
10	7.5	7.5	7
20	14.5	~~14.5~~ 25	14.5
30	22	22	22

FLUID COLUMN HEIGHT (cm)	READING FROM MANOMETER ON SMALL CYLINDER 50% 2-PROPANOL IN WATER	50% SUCROSE IN WATER
10	6.5 mmHg	9 mm Hg
20	13	18
30	20	~~27~~ 27.5

FIND THE DENSITY OF WATER (SMALL CYLINDER, WATER COLUMN HEIGHT = 10 cm)

$$\rho = \frac{\Delta P}{g(-\Delta z)}$$

$$\Delta P = 7.5\ (\text{mmHg}) \cdot \frac{101325\ \text{Pa}}{760\ \text{mmHg}} = 1000\ \text{Pa} = 1000\ \frac{\text{kg}}{\text{m s}^2}$$

$$g = 9.8\ \text{m/s}^2$$

$$-\Delta z = 10\ \text{cm} \cdot \frac{1\ \text{m}}{100\ \text{cm}} = 0.1\ \text{m}$$

$$\rho = \frac{1000\ \frac{\text{kg}}{\text{m s}^2}}{9.8\ \frac{\text{m}}{\text{s}^2} \cdot 0.1\ \text{m}} = 1020\ \frac{\text{kg}}{\text{m}^3} \cdot \cancel{\frac{100^3\ \text{cm}^3}{\text{m}^2}}\ \frac{1\ \text{m}^3}{100^3\ \text{cm}^3} \cdot \frac{1000\ \text{g}}{1\ \text{kg}}$$

OOPS

$$= 1.02\ \frac{\text{g}}{\text{cm}^3}$$

FIND THE DENSITY OF 50% 2-PROPANOL IN WATER

$$\Delta P = 13\ \text{mmHg} \cdot \frac{101325\ \text{Pa}}{760\ \text{mmHg}} = 1733\ \text{Pa} = 1733\ \frac{\text{kg}}{\text{m s}^2}$$

$$g = 9.8\ \frac{\text{m}}{\text{s}^2}$$

$$-\Delta z = 20\ \text{cm} \cdot \frac{1\ \text{m}}{100\ \text{cm}} = 0.2\ \text{m}$$

$$\rho = \frac{1733\ \frac{\text{kg}}{\text{m s}^2}}{9.8\ \frac{\text{m}}{\text{s}^2} \cdot 0.2\ \text{m}} = 884\ \frac{\text{kg}}{\text{m}^3} \cdot \frac{1\ \text{m}^3}{100^3\ \text{cm}^3} \cdot \frac{1000\ \text{g}}{\text{kg}} = 0.884\ \frac{\text{g}}{\text{cm}^3}$$

Group Assessment Form

This form must be submitted by each member of the group.

Evaluate each member of your group (including yourself in terms of how each member performed relative to what the group expected of that individual in attending and participating in the lab and preparing editing and submitting the assignments.

Use a scale of 0-10, where

- 0 represents ‘did not meet any of the expectations’
- 10 represents ’fully met all expectations’.

Member name	**Rating (0-10)**
(me)	

Essential Web Resources for CBE Students

Wikipedia and Google do not know everything. *Wikipedia* is a reliable source for most science and engineering topics. Like all texts (print or electronic) it does contain some errors and misinformation. CBE students at CSU should be familiar with the other web resources on this list. The sources are trusted and some are suitable to be used as primary sources (e.g. it is appropriate to cite them as a reliable source in homework, reports, or publications). Others are simply helpful compilations of useful information.

URLs are subject to change.

1. Resources about Chemical and Biological Engineering:

 Our department website - The definitive source for authoritative information about our program and classes. cbe.colostate.edu/

 The American Institute of Chemical Engineers - The professional organization with lots of information for all things related to our profession. www.aiche.org/

 The Society for Biological Engineers - A group of biological engineers within AIChE. www.aiche.org/sbe/

2. Authoritative texts, available electronically through the CSU library's website. If you are on campus, you should be able to access these texts on your computer. Alternatively, you could actually visit the library in person and read a real book!

 CRC Handbook of Chemistry and Physics - An essential compilation of data important for anyone working in the physical sciences and engineering.

 Perry's Chemical Engineer's Handbook - The go-to source for a primer on just about any fundamental topic in the core sub-disciplines of CBE. This book also contains lots of useful data.

 Kirk-Othmer Encyclopedia of Chemical Technology - A relatively comprehensive collection of articles on many chemical engineering topics.

 The Knovel Library - A very large collection of web books in science and engineering. Many of these broad categories are useful for CBE's, but the most important is the "Chemistry & Chemical Engineering" category. From there, browse the subtopics to see how things are arranged. This library contains very valuable handbooks and classic textbooks in chemical engineering. *The Knovel Library* is updated with new editions and new texts as they become available. Treasures buried here include:

DIPPR - Design Institute for Physical Properties is a source for physical, thermodynamic and transport properties.

The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals.

Polymer Handbook - Physical properties and reactions of polymers and monomers.

Properties of Gasses and Liquids - A handbook for thermodynamic properties and phase equilibria of fluids.

3. Alternatives to *Wikipedia* - Online sources for physical properties and engineering data include:

NIST Chemistry WebBook - A standard reference for chemical properties.
webbook.nist.gov/

IUPAC Goldbook - IUPAC Compendium of Chemical Terminology.
goldbook.iupac.org/

The Engineering Toolbox - Lots of standard information here. Think of this when you're looking for something that should be an appendix in a book on your shelf, but you aren't even sure which book has that appendix.
www.engineeringtoolbox.com/