CBE 154: Chemical Engineering Laboratory

Spring 2015 Course Syllabus

Instructional Staff

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Course Goals

This course is one of the two capstone courses in the chemical-engineering curriculum, along with Chemical Process Design (CBE 160). In these courses you begin to prepare for a role as a professional chemical engineer in industry or academia. As a result, this course differs from most of your previous ones. Rather than teaching a specific set of fundamental relations and concepts governing a particular subject (i.e., thermodynamics or transport), this course requires that you integrate and apply knowledge from all of your previous courses to design experiments, collect data, analyze the results, and make recommendations. Importantly, you will also work on developing your oral and written communication skills.

In this course, students will learn to:

- design experiments to obtain relevant data;
- troubleshoot processes;
- conduct experiments utilizing typical CBE process equipment;
- utilize numerical software packages to simulate transport phenomena and thermodynamics;
- make, test, and justify assumptions;
- analyze data appropriately to extract parameters of interest;
- characterize, quantify, and report error in results and calculations;
- apply analysis to answer questions such as scale-up; and
- present technical information effectively in written and verbal form.

You will achieve these goals by performing a set of six experiments over the course of the semester. The mechanics of this course are complicated, so please read through the syllabus to obtain necessary information about how the course will run, what assignments you must complete, how you will be graded, and other important course policies.

Course Website & Computing Resources

The course website is maintained on bCourses and contains lab manuals, references, and announcements. You should be enrolled automatically. Please contact Dr. Cerretani if you have access problems.

The Chevron Computing Facility in 175 Tan Hall provides computer access, including for COMSOL and Aspen, for all enrolled students. Login information is below:

Username: !chmfcheme154
Password: c@1academics

Please refer to the website for facility hours: http://ets.berkeley.edu/computer-facilities/tamf

Course Outline

Groups

You will self-assemble into 3-member groups of your choosing during the first lab meeting. Each group must complete all of the experiments and assignments together unless otherwise noted. We expect all group members to contribute equally. Honest communication among group members is necessary for optimal group functioning, so please address any group issues before they grow.

Experiments and Rooms

Each group completes 6 experiments during the semester. You are allotted 4 lab periods to collect data for each experiment. Groups are pre-assigned a sequence of experiments at the beginning of the semester. This information can be found in the schedule posted on bCourses. Table 1 lists the experiment names and codes categorized by topic along with the requirements. The experiments with duplicate setups are numbered (i.e., HT1, HT2; DIST1, DIST2). There are signs on the wall or on the setup indicating which apparatus is which. Check the schedule to see which apparatus your group is scheduled to use.

Table 1: Experiment categories, names, and codes. Notes in parentheses indicate required experiments from each category.

Category (# required labs from category)	**Experiment Name**	**Code(s)**
Transport (2 of 2 experiments)	Heat-Transfer Modeling	HT1, HT2
	Mass-Transfer Modeling	MT1, MT2
Chemical Reactions (1 of 2 experiments)	Absorption with Reaction	AR
	Sucrose-Inversion Kinetics	CEU
Separations (2 of 2 experiments)	Distillation	DIST1, DIST2
	Membrane Separation	MS1, MS2
Fluid Mechanics (1 of 3 experiments)	Centrifugal Pump	CP
	Flow Measurement	FM
	Fluidized and Packed Beds	FB
Total (6 of 12 experiments)		

The experiments are housed in S1 Gilman Hall and 33/35 Lewis Hall. Access to S1 Gilman is only available via the external door on the south side of Gilman Hall. Please review the maps uploaded to bCourses that show the location of experiments, emergency exits, and first-aid/safety equipment in each room. A GSI will always be present in each room. The land-line phone numbers for the rooms are:

S1 Gilman: (510) 642-0358
33/35 Lewis: (510) 642-5862

Lab Notebooks and Data Collection

All students must maintain a formal laboratory notebook over the course of the semester. The notebook must have numbered pages, a table of contents in the beginning, and be permanently bound. Pre-lab exercises, brief procedures, raw data, observations, sample calculations, and important results should be included in the laboratory notebook. At the beginning of a new experiment, the GSIs will check each group member's lab notebook to confirm that the pre-lab exercises are completed. Students must bring their lab notebooks to every lab period and all presentations. The notebook section for each experiment must be complete by the oral presentation. The GSIs will grade lab notebooks at the end of the semester according to the rubric available on the course website. For additional guidelines on lab-notebook practices, see *Writing the Laboratory Notebook* by H. M. Kanare (full reference in **Textbooks** section of syllabus). For more information on acceptable lab notebook formats and practices, please see the "Lab Notebook" pdf file on the course website.

Assignments

Each experiment in this course carries at least one graded report, possibly two. Four experiments (reactions, fluid mechanics, and both separations) culminate in an oral report delivered to the instructor 1-2 lab periods after completion of the experiment. For the first of the two transport experiments, groups deliver a presentation during the third lab period. After both transport experiments, students turn in a written report two lab periods after completion of the experiment. Details on each type of assignment are included below.

Pre-lab exercises

Listed in the manual for each experiment are required pre-lab exercises that familiarize students with the concepts, apparatus, and safety issues relevant to that experiment. These questions must be completed before the group may begin any experiment. At the beginning of the first day of each new experiment, the GSIs will confirm that all group members have the pre-lab exercises completed in the lab notebooks. No group member may use the lab equipment unless he or she has been cleared by the GSI. Students must complete the pre-lab exercises before the end of the first lab period of each new experiment.

Oral reports

For all experiments except one, the group will deliver an oral presentation to the instructor describing the important findings of the experiment. In 3-member teams, each member will have the opportunity to be the lead presenter for 1 report, a secondary presenter for 2 reports, and a co-lead presenter for a 4th report and the transport report. For 4-member teams, each team member will be the lead presenter for 1 report, a secondary presenter for 3 reports, and a co-lead presenter for the transport oral report. For a particular experiment, the lead presenter is expected to organize the team's efforts for data collection, data analysis, and presentation of the results and conclusions. As in the professional workplace, all members are expected to work equally for each experiment, regardless of who is lead. During the oral presentation, the lead presenter must deliver the entire presentation. However, other group members may answer questions if necessary.

Oral reports take place ***in the instructor's office*** at the times listed in the schedule on the course website. Within the 45-min time slot, 15 min are allotted for the presentation and 15 min for questioning from the instructor. The instructor will utilize the remaining 15 min for presentation feedback. Accordingly, **each presentation must contain no more than 10 content slides**, not including the title and reference slides. Please bring to the presentation one printed copy of the presentation, all group members' lab notebooks, and a copy of the appendices containing the experimental data and detailed calculations. **A copy of the presentation in PowerPoint and PDF must be emailed to cbe154lab@gmail.com no later than 10 AM on the day of the presentation.** Reports submitted from 10am – 1pm receive a 5-pt penalty and those after 1pm receive a 10-pt penalty. The subject line of the email must indicate the group number and the experiment abbreviation, i.e. '*MW1-DIST*'. Groups will present from the instructor's laptop with the report emailed to the course email address listed above. Students will have access to a projector, blackboard, and wireless presentation remote/laser pointer.

Oral reports concluding the separations, reactions, and fluid mechanics experiments occur 1 lab period after experiment completion. The format of these presentations is analogous to a new engineer in a company presenting to his/her boss during a project-review meeting. The oral report is a presentation of the student group's data, the conclusions derived from those data, and the logical reasoning used to reach these conclusions. Each presentation should tell a coherent story; do not simply answer analysis questions in order. Presentations should include the experimental objective(s), a brief description of the experimental approach, relevant theory and literature, important results, and conclusions. Students should expect in-depth questions that may extend beyond the narrow area of the presentation and into any aspect of the experiment. Keep in mind that technical ideas are often best communicated in equations and diagrams; therefore, students are encouraged to answer questions at the board.

During the **third lab period of the first transport experiment** (HT or MT), students will deliver a group oral report summarizing briefly their experimental approach, analysis, and important findings. Students are expected to compare their experimental results to theoretical expectations and literature predictions and to display important trends in the data. The focus of

the HT oral report is on the second part of the experiment, but both parts must be addressed. Therefore, allocate approximately one-third of your presentation to the first part and two-thirds to the second part. The 15-min presentation is followed by a discussion with the instructor to help assess the technical understanding of the lab and to assist in the completion of the COMSOL modeling and the written report, which are completed individually.

Oral reports are graded according to the "Oral Report Rubric" located under the folder "Rubrics & Templates" in the "Files" section of the bCourses site.

Written reports

The HT and MT experiments conclude with a written report to be completed individually by each student. **Written reports are due in class two lab periods after completion of the transport experiments.** Hand in a bound copy of the written report to your GSI at the beginning of the lab period. Reports are to be bound with an inexpensive, clear-cover report folder. Additionally, **a copy of the written report in Word and PDF must be emailed to cbe154lab@gmail.com before lab starts on the due date.**

Reports should be written from the point of view of a new engineer at a company tasked with assessing the feasibility of utilizing COMSOL software to simulate specific transport phenomena. Thus, the focus is not on the experiment per se, but on the simulation and its agreement with the experiment and theory. You **DO NOT** need to address Part 1 of HT; only address the experiments and modeling in Part 2. The objectives for both the HT and MT written reports are similar. In both reports, you need not describe the exact experimental procedure in detail. Instead, describe the aspects of the experiment necessary for the reader to understand what physical situation the COMSOL code attempts to simulate and which results are to be matched. The written reports should follow the template provided online entitled "Written Report Template". Within the template are descriptions of what information to include in each section. Note that technical information is often best conveyed with figures and tables. The **key figures must appear in the main text** at a legible size.

The report should be concise: the **main body of the report must be no longer than 5 pages including tables and figures** (12-pt Times New Roman font, single-spaced, 1" margins, single-sided). Accordingly, include only the most important results in the main body. The report may include up to 10 pages of appendices consisting of tables, figures, equations, or text that support the main body. The appendices should include, in a comprehensive and organized fashion, all of your relevant calculations and how they relate to the experiments and your design. Reference the appendices in the main text as needed, but recognize that only the main body is carefully studied by the reader. Any reports turned in on time but not meeting the criteria outlined above will be considered unacceptable and must be resubmitted the next day subject to a 5 pt penalty. Subsequent late days follow the regular 10 pt/day penalty (see policy on late assignments). For more information about style and conventions in technical writing, the American Chemical Society (ACS) provides a useful online guide called The ACS Style Guide. Information on figures, tables, grammar, writing style, references, etc. will be useful for your writing in this course.

Written reports are graded according to the "Written Report Rubric" located on the bCourses site. Detailed comments will be returned with the report. The instructors keep copies of the written report for the departmental records. One week after turning in the first written report, each student will have a 10-min individual conference (indicated in the schedule) with the instructor to discuss areas for improvement in the next written report.

Lectures

At the beginning of the semester, there will be a few introductory lectures by the instructor. After this, there will be guest lectures each Monday 12-1 pm in 9 Lewis Hall. Please find information about the guest lectures on the bCourses site under "Pages"→"Guest Lectures". These lectures are meant to provide you with basic chemical-engineering knowledge and a perspective on possible careers as a professional chemical engineer. Each week, the instructors will send out reminder emails about the upcoming guest lecture.

Office Hours

Dr. Cerretani and the GSIs are generally available for questions during class time Mon-Thu 1-5 pm. We are happy to help clarify the experimental objectives and tasks, to assist with COMSOL/Aspen issues, and to point you in the right direction. However, we will not tell you exactly what to do or whether you're "doing the right thing". There are multiple ways of approaching a problem and you must practice exercising your own judgment. We will address logistical questions (i.e., scheduling issues, assignment clarifications) via email, but we *will not* do the same for technical questions. You should utilize the 16 hr of weekly class time to address technical questions. Likewise, you are responsible for informing the GSIs or instructors early on if your data or simulation does not make sense. This way, we can address any problems well before the oral or written report is due.

Schedule

The semester schedule is posted on the bCourses website. Labs begin almost immediately and the semester is packed, so download the schedule and identify which labs your group must complete and the dates when you are to present. Within the schedule Excel file, there are sheets showing the daily lab schedule as well as the times and dates of all oral presentations. Note important dates in your calendar and contact the instructor ASAP if you have pre-planned conflicts. Labs are Monday/Wednesday (Section 101) and Tuesday/Thursday (Section 102) 1-5 pm. Lectures are Mondays 12-1 pm in 180 Tan Hall.

Lab Safety

It is critical that students follow proper safety protocol at all times while in lab. This includes completing pre-lab safety exercises prior to beginning each experiment, following laboratory rules, adhering to relevant SOPs, and knowing where to find safety information and equipment in the laboratory.

Before each lab, students must read the lab manual to ensure familiarity with proper safety protocols. Please review all Standard Operating Procedures (SOPs) associated with hazardous chemicals to be used in a particular experiment prior to arriving in lab. SOPs can be found in the folder labeled "Standard Operating Procedures (SOPs)" on the bCourses site.

It is imperative that students wear lab safety goggles at ALL times while in lab. Wear closed-toed shoes and long pants; avoid wearing loose clothing; tie back long hair. Only bring required material (i.e., lab notebook, pen, calculator, laptop, …) into the lab area. Backpacks and other personal items must be left in the designated areas. **Food and drink are not allowed in the lab at any time.** Before beginning an experiment, note the location of exits, first-aid kits, and emergency eyewash stations. These locations are shown in the maps of each room uploaded to the course website.

During the experiment, use common sense and ask the GSI if there are any questions on the safe operation of the lab equipment. Some experiments contain pressurized vessels, moving parts, noxious chemicals, and hot surfaces, so please exercise caution.

Course Policies

Grading

Detailed grading rubrics are available on the bCourses website for written reports, oral reports, and lab notebooks. You are strongly advised to look through these rubrics to understand how your assignments are assessed. You will receive completed rubrics after each assignment so that you may identify areas for improvement. The grade will reflect both the technical content of the report and the quality of the writing or presentation. Numerical scores follow these approximate guidelines:

95-100 %	Exceptional quality, analysis/presentation above and beyond expectations
85-95 %	Solid understanding of physics, rigorous error analysis, comparison to literature, well-executed written report/presentation
75-85 %	Fundamental understanding of basic concepts, basic analysis complete, able to answer technical questions
65-75 %	Experimental tasks complete, but multiple gaps in understanding, incomplete analysis, lack of ability to answer questions
< 65 %	Multiple experimental tasks incomplete, unacceptable writing/presentation

Scores will be uploaded to the bCourses website periodically during the semester. Please check these against your records.

Tables 2A and 2B below describe the grade breakdown for each experiment and each group member for 3- and 4-member groups. The percentages listed are the partial contribution of each assignment to an individual's course grade. Three of the oral reports require a team leader (points in red) and the rest assign points equally among the group members. See the *Oral Reports* section for information on the leader's role. Groups may decide which member is lead for each report. The fluid mechanics presentation is always shared, except for 4-member groups.

Table 2A: Point breakdown for 3-member team, red indicates team leader.

Experiment category	*Report type*	*Member 1*	*Member 2*	*Member 3*
1st transport modeling	Oral	6%	6%	6%
1st transport modeling	Written	17%	17%	17%
2nd transport modeling	Written	17%	17%	17%
Chemical reaction /	Oral	18%	8%	8%
1st separations /	Oral	8%	18%	8%
2nd separations /	Oral	8%	8%	18%
Fluid mechanics	Oral	16%	16%	16%
Participation and lab notebook	N/A	10%	10%	10%

Table 2B: Point breakdown for 4-member team, red indicates team leader.

Experiment category	*Report type*	*Member 1*	*Member 2*	*Member 3*	*Member 4*
1st transport modeling	Oral	6%	6%	6%	6%
1st transport modeling	Written	17%	17%	17%	17%
2nd transport modeling	Written	17%	17%	17%	17%
Chemical reaction /	Oral	20%	10%	10%	10%
1st separations /	Oral	10%	20%	10%	10%
2nd separations /	Oral	10%	10%	20%	10%
Fluid mechanics	Oral	10%	10%	10%	20%
Participation & lab notebook	N/A	10%	10%	10%	10%

Late assignments/rescheduling

The course organization is complicated, so rescheduling presentations is difficult. With the exception of family and medical emergencies, no late assignments will be accepted for full credit. For planned medical or other absences, please notify the instructor as early as possible.

Oral reports: Presentations begin on the hour and the half hour. “Berkeley time” does NOT apply. Any unexcused absences may be rescheduled within 1 week of the scheduled time for 50 % credit. Electronic submissions of oral reports after 10 am are considered late. Submissions from 10am – 1pm receive a 5-pt penalty and those after 1 pm receive a 10-pt penalty.

Written reports: Both the electronic and hard copies of written reports are due at 1:10 pm on the due date. Late submissions are subject to a penalty of 10 pts per day. Submit late

reports Mon-Thu to the GSI in S1 Gilman or 33 Lewis at the usual time. Reports on Friday should be placed in the appropriate instructor's mailbox inside 201 Gilman Hall and he or she must be informed by email. To turn in a report on the weekend, email an electronic copy to the che154lab@gmail.com cc-ing the appropriate instructor. If an identical hard copy is turned in on Monday, then the electronic submission date will be recorded as the official submission date. If not, then the day the hard copy arrives will be the official submission date. Reports will not be accepted more than 5 days late.

Academic (dis)honesty

All written and oral reports will be assessed for evidence of plagiarism, which, if found, will result in a grade of **zero** and further disciplinary measures. Additionally, forging of data will be treated with a grade of zero and further disciplinary measures. Plagiarism is the presentation of the work or words of others as your own. Electronic versions of presentations and written reports will be compared against reports turned into CBE 154 this year and in previous years. Instances of plagiarism will be reported to the UC Berkeley Office of Student Judicial Affairs (http://sja.berkeley.edu). Please see this link from Dr. C. Barnbaum at Valdosta State University for helpful information on types of plagiarism and how to avoid them.

Textbooks

Primary texts:

McCabe W.L., Smith J.C., Harriott P. *Unit Operations of Chemical Engineering*, 7th ed.; McGraw-Hill: New York, 2005. "MSH", *CHM

Seader J.D., Henley E.J., Roper D.K. *Separation Process Principles*, 3rd ed.; Wiley: New York, 2011. "SHR", *CHM

Other suggested texts:

Bird R.B., Stewart W.E., Lightfoot E.N. *Transport Phenomena*, 2nd ed.; Wiley: New York, 2002. "BSL", *CHM

Kanare H.M. *Writing the Laboratory Notebook*; American Chemical Society: Washington DC, 1985. *CHM

Smith J.M., Van Ness H.C., Abbott M.M. *Introduction to Chemical Engineering Thermodynamics*, 7th ed.; McGraw-Hill: New York, 2005. "SVA"

Taylor J.R. *An Introduction to Error Analysis*, 2nd ed.; University Science Books: Herndon VA, 1997. *CHM

Welty J.R., Wicks C.E., Wilson R.E., Rorrer G. *Fundamentals of Momentum, Heat, and Mass Transfer*, 4th ed.; Wiley: New York, 2001. "W3R", *CHM

"XX" = book abbreviation, *CHM = on reserve in the Chemistry library