CBE 154: Chemical Engineering Laboratory

Fall 2016 Course Syllabus

Instructional Staff

Name	*Role*	*Email*	*Office*
Prof. Markita Landry	Instructor	landry@berkeley.edu	222 Gilman Hall (oral reports) 476 Stanley Hall (office hours)
Dr. Alexandra Landry	Instructor	amlandry@berkeley.edu	313 Gilman Hall
Prof. Ali Mesbah	Instructor	mesbah@berkeley.edu	316 Gilman Hall
Esayas Kelkile	Lab Engineer	esayask@berkeley.edu	
Jeremy Seidel	GSI	jeremy.seidel@berkeley.edu	
Ari Fischer	GSI	ari.fischer@berkeley.edu	

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
- 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. A. Landry if you have access problems.

The Chevron Computing Facility in 175 Tan Hall provides computer access, including COMSOL and Aspen, for all enrolled students. Log in with your CalNet ID and password. Please refer to the facility website for its hours: http://ets.berkeley.edu/computer-facilities/tamf.

Course Outline

Schedule

The semester schedule is posted in an Excel file on the bCourses website. Labs begin the second week 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) from 1-5 pm in either S1 Gilman Hall or 33 Lewis Hall. We will only accommodate requests to switch between lab sections before the start of labs.

Lectures

At the beginning of the semester, there are a few introductory lectures by the instructor. After this, there are 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.

Groups

You will self-assemble into 3- and 4-member groups of your choosing during the first class 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. Three peer evaluations collected during the semester serve to assess individual contributions to the group assignments. They form part of your course participation grade. See grading section for more information.

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 or 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, codes, and rooms. Notes in parentheses indicate required experiments from each category.

Category (# required labs from category)	**Experiment Name**	**Code(s)**	**Room**
Transport (2 of 3 experiments)	Heat-Transfer Modeling	HT1, HT2	Lewis
	Mass-Transfer Modeling	MT1, MT2	Lewis
	Immersion Heat Exchanger	IHX	Lewis
Chemical Reactions (1 of 3 experiments)	Absorption with Reaction	AR	Gilman
	Sucrose-Inversion Kinetics	CEU	Lewis
	Fermentation Kinetics	FERM1, FERM2	Lewis
Separations (2 of 3 experiments)	Distillation	DIST1, DIST2	Gilman
	Membrane Separation	MS1, MS2	Gilman
	Reverse Osmosis	RO	Gilman
Fluid Mechanics (1 of 3 experiments)	Centrifugal Pump	CP	Gilman
	Flow Measurement	FM	Gilman
	Fluidized and Packed Beds	FB	Gilman
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 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. We grade the 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 Dos and Don'ts" 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 one or two lab periods after experiment completion. See the schedule for details. For the two transport experiments (HT and MT), groups deliver an oral 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, the group delivers an oral presentation to the instructor describing the important findings of the experiment. In 3-member teams, each member has the opportunity to be the lead presenter for one report, a secondary presenter for two reports, and a co-lead presenter for a fourth report and the two transport reports. For 4-member teams, each team member is the lead presenter for one report, a secondary presenter for three reports, and a co-lead presenter for the two transport oral reports. 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. 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,15 min for questioning from the instructor, and 15 min for feedback. Accordingly, **each presentation must contain no more than 10 content slides**, not including the title slide. 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 che154lab@gmail.com no later than 10 AM on the day of the presentation.** The subject line of the email must indicate the

group number and the experiment abbreviation, i.e. '*MW1-DIST*'. Groups present from the instructor's laptop with the report emailed to the course email address listed above. If students wish to present from their own laptop, they must arrive with the laptop on and the presentation open. Students have access to a projector, blackboard, and wireless presentation remote/laser pointer.

Oral reports concluding the separations, reactions, and fluid mechanics experiments occur one or two lab periods after experiment completion. See the schedule for exact timing. 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 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 objectives, a brief description of the experimental approach, relevant theory and literature, important results, and conclusions (not necessarily in this order). We recognize that the data collected within the four lab periods may not match expectations. Address inconsistencies between data and expectations in the report and provide conclusions and suggestions for improvement. 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 utilize the board when answering instructor questions.

During the **third lab period of the HT and MT experiments**, students 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 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 *Rubrics & Templates* folder 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 che154lab@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 alone, but on the simulation and its agreement with the experiment and theory. 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 10 pt penalty. Subsequent late days follow the regular 20 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.

Office Hours

Dr. A. Landry and the GSIs are generally available for questions during class time Mon-Thu 1-5 pm. Prof. M. Landry is available Mondays and Tuesdays from 4-5 pm. Prof. Mesbah is available Wednesdays and Thursdays from 4-5 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 h 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.

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 and a lab coat 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 concerns about 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 we assess your assignments. You receive completed rubrics after each assignment so that you may identify areas for improvement. The grade reflects both the technical content of the report and the quality of the writing or presentation. Scores are uploaded to the bCourses website periodically during the semester. Please check these against your records.

Tables 2A and 2B 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 overall 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.

The lab notebook score is based on the quality of your lab notebook, assessed at the end of the semester. The lab-notebook grading rubric appears on bCourses.

Your attendance, lab preparation, and peer-evaluation scores all contribute to your participation score. GSIs keep track of lab attendance and prelab preparation. You will receive email links to submit peer evaluations of your group members three times during the semester. These evaluations are required. Each group member evaluates the other members of his or her

team. For a three- or four-person group, each team member has 20 or 30 pt to distribute among the other two or three group members, respectively. If all members contribute equally, the average score is 10. If team members earn peer-evaluation scores significantly less than 10, the instructors will reduce participation scores accordingly.

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	5%	5%	5%
1st transport modeling	Written	15%	15%	15%
2nd transport modeling	Oral	5%	5%	5%
2nd transport modeling	Written	15%	15%	15%
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	N/A	5%	5%	5%
Lab notebook	N/A	5%	5%	5%

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	5%	5%	5%	5%
1st transport modeling	Written	15%	15%	15%	15%
2nd transport modeling	Oral	5%	5%	5%	5%
2nd transport modeling	Written	15%	15%	15%	15%
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	N/A	5%	5%	5%	5%
Lab notebook	N/A	5%	5%	5%	5%

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 at the time indicated on the schedule. "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 and subject to 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 20 pts. per day. Reports are not accepted more than 2 days late. 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 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.

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