# CHE 451: Senior Laboratory (Section 002)

# Tuesday 12:30 – 4:45, 249A ESB and G51E/F

### **Spring 2019**

### Course Instructor: Sushant Agarwal

#### Office Location: B61E1, ESB (lab near distillation column)

### Office Hours: Monday 3:30 – 4:30 or by appointment

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###### Recommended Texts: Texts for all previous ChE courses

J. M. Haile, *Technical Style*, Macatea (2002)

L. Truss, *Eats, Shoots and Leaves: The Zero Tolerance Approach to Punctuation*, Fourth Estate, London (2009)

***This Outline must be read in conjunction with the Laboratory Manual for the course.***

### **Course Goal**: To consolidate and solidify the concepts and knowledge you have acquired during the undergraduate program, in a hands-on and communications framework.

#### 1. Learning Outcomes

In partial fulfillment of *ChE Educational Outcomes 2, 3, 4, 5 and 7* (see “Undergraduate Program Mission, Outcomes and Objectives” statement), at the conclusion of this course, you will:

* develop the ability to design and to perform laboratory experiments from a general problem statement and relevant literature suggested;
* become familiar with process equipment and instrumentation similar to that found in actual plant or research environments;
* integrate the principles learned in classes with laboratory operation and practice;
* learn how to document data and ideas appropriately in a laboratory notebook;
* analyze experimental data using basic chemical-engineering principles;
* communicate effectively in both written and oral formats;
* develop interpersonal skills necessary for team performance;
* practice standard laboratory safety procedures and follow good environmental practice.

#### 2. Summary of Important Course Policies

1. Laboratory work must be carried out on the scheduled dates with all team members present. All team members must be present on lab days for the team to participate in the lab. Please schedule job interviews and work on the design project accordingly. University and valid medical excuses will, of course, be accepted.
2. The team is responsible for reading and understanding the laboratory manual and any supplemental or reference material provided. The team should seek additional reference material regarding their experiment.
3. On the first lab day of each cycle, a Pre-laboratory Report (“Pre-lab”) is submitted to the GTA and approved before experimental work begins. On the third week of the cycle, the team meets with the instructor for the Data Analysis Review. On the sixth week of the cycle, a Written Report is submitted and an Oral Presentation is made. More details on all of these are provided below.
4. All written reports must be neatly printed double-spaced using word-processor software in the format described in the manual.
5. Each team member must participate in every activity. Students not present will be deducted the appropriate number of points. University and valid medical excuses will be accepted.
6. You may examine equipment during normal working hours but under no circumstances are you to work on or to operate an experiment alone or without proper supervision.
7. Laboratory safety procedures are of paramount importance and will be strictly enforced. If you are not sure about something, please ask!!

**3. Course Schedule**

This course consists of two, six week laboratory cycles. Each cycle represents a different experiment. The course schedule is shown in Table 1.

# Table 1. Course Schedule

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Semester Week #** | **Cycle#/**  **Week#** | Activity | **Date** | **Location** |
| 1 | NA | **Introduction** | 01/08/19 | **249A ESB** |
| 2 | NA | Pre-lab Walkthrough | 01/15/19 | Galli Lab |
| **3** | **1/1** | **Lab Day / Pre-laboratory Report** | **01/22/19** | **Galli Lab** |
| 4 | 1/2 | Lab Day | 01/29/19 | Galli Lab |
| **5** | **1/3** | **Data Analysis Review /**  **Lab open with TA supervision** | **02/05/19** | **249A ESB** |
| 6 | 1/4 | Lab Day | 02/12/19 | Galli Lab |
| 7 | 1/5 | Lab Day | 02/19/19 | Galli Lab |
| **8** | **1/6** | **Oral Presentations/Laboratory Report/Pre-lab Walk through** | **02/26/19** | **249A ESB** |
| **CYCLE 2** | | | | |
| 9 | 2/1 | **Lab Day / Pre-laboratory Report** | 03/05/19 | Galli Lab |
|  | **NA** | **Fall Recess** | **03/12/19** |  |
| 10 | **2/2** | Lab Day | 03/19/19 | Galli Lab |
| **11** | 2/3 | **Data Analysis Review /**  **Lab open with TA supervision** | **03/26/19** | **249A ESB** |
| 12 | **2/4** | Lab Day | 04/02/19 | Galli Lab |
| 13 | 2/5 | Lab Day | 04/09/19 | Galli Lab |
| 14 | 2/6 | **Oral Presentations / Laboratory Report** | **04/16/19** | **249A ESB** |

**4. Student and Team Performance**

For each cycle, each team will submit ***a Pre-laboratory Report, a Data Analysis Report, and a Final Laboratory Report.*** In addition, the results of the laboratory report will be presented orally. The due dates and grade weighting of each of these are shown in Table 2.

# Table 2. Laboratory Grade Weighting

|  |  |  |
| --- | --- | --- |
| **Cycle Activity** | **Due Date** | **Points** |
| Pre-laboratory Report | Cycle Week 1 | 50 |
| Data Analysis Review | Cycle Week 3 | 50 |
| Oral Presentation | Cycle Week 6 | 50 |
| Laboratory Report | Cycle Week 6 | 100 |

Numerical grades, not letter grades, will be issued for reports and presentations. Each team member must participate in every activity (lab days, presentations, walkthroughs, etc.) and may earn up to 500 total points for the semester. ***If a student is not present, for an activity, the student’s total points will be calculated and 1/12 of that total will be deducted per unexcused absence.*** The score of other team members will, of course, be unaffected. University and valid medical excuses will be accepted.

Letter grades will be issued only for the overall performance in the course. The following serve as “ceilings” of minimum performance to receive the corresponding grades: “A”=90, “B”=80, “C”=70, “D”=60. They are “ceilings” in that they may be adjusted downwards.

5. Cycle Sequence and Report Preparation

A short memorandum to each team will initiate each laboratory cycle. This memo will provide a brief description of a problem (experiment) and will describe the task assigned. Each team needs to discuss this memorandum and do the background work necessary to start the project. A list of the experiments (and experiment numbers) is given in Table 3, and the assignments for each team are given in Table 4.

### **Table 3. List of Experiments**

|  |  |
| --- | --- |
| **Experiment #** | **Name of Experiment** |
| ~~1~~ | ~~Process Control~~ |
| 2 | Convective Heat Transfer |
| 3 | Distillation Column |
| 4 | Dye Fading |
| 5 | Pressure Drop |
| 6 | Residence Time Distribution |
| 7 | Enzyme Kinetics |
| 8 | Tank Drainage |
| 9 | Fluidized Bed |
| ~~10~~ | ~~Thermal Conductivity in Spheres~~ |

#### Table 4. Student Team and Experiment Assignments for Each of the Two Lab Cycles

|  |  |  |
| --- | --- | --- |
| **Team #** | **Experiment #**  **Cycle 1** | **Experiment #**  **Cycle 2** |
| 1 | 8-tank drainage | 4- dye fading |
| 2 | 9- fluidized bed | 7- enzyme kinetics |
| 3 | 2- convective HT | 8- tank drainage |
| 4 | 3- distillation column | 6- RTD |
| 5 | 5- pressure drop | 3- distillation column |
| 6 | 6- RTD | 5- pressure drop |
| 7 | 7- enzyme kinetics | 2- convective HT |
| 8 | 4- dye fading | 9- fluidized bed |

**A. Pre-laboratory Walkthrough and Pre-Lab Report**

The week before the experimental work is begun each team will have the opportunity to meet with the GTA and examine the lab equipment and review the experiment. The Pre-Lab Walkthrough schedule is given in Table 5. The next week, (cycle week #1) a neatly written experimental plan (Pre-laboratory Report / “Pre-lab”) must be submitted to the GTA or instructor and approved before experimental work is begun. The Pre-lab Report schedule is given in Table 6. Pre-laboratory Reports will be graded for content by the GTA. See Appendix I for grading criteria.

**Table 6 Pre-lab Report Schedule1,2**

|  |  |  |
| --- | --- | --- |
| **Team #** | **Cycle 1**  **Week 1** | **Cycle 2**  **Week 1** |
| Team 1 | Arrange with TA | |
| Team 2 |
| Team 3 |
| Team 4 |
| Team 5 |
| Team 6 |
| Team 7 |
| Team 8 |

1Clearly some teams will not have the full lab time on this day, however ample lab time has been scheduled throughout the cycle to make up for this.

2Please be prepared and present slightly ahead of your scheduled time so the transition between teams goes smoothly.

**Table 5. Pre-lab Walkthrough Schedule1**

|  |  |  |
| --- | --- | --- |
| **Team #** | **Week #2** | **Week #8** |
| Team 1 | Arrange with TA | |
| Team 2 |
| Team 3 |
| Team 4 |
| Team 5 |
| Team 6 |
| Team 7 |
| Team 8 |

1Please be prepared and present slightly ahead of your scheduled time so the transition between teams goes smoothly.

**B. Data Analysis Review**

Teams will meet with the instructor to present and discuss the Data Analysis Review. This report will be based on the data from the first two lab days. The team will have available for inspection and discussion: a) the data (Excel format), b) essential equations (theory) needed for analysis of the data (Power Point format), c) essential calculations (Excel format), and d) properly labeled graphs (Excel plots) of the data as well as graphs essential for analysis of the data. The meeting schedule for the Data Analysis Report is given in Table 7. The Data Analysis Review will be graded for completeness and correctness. See Appendix II for grading criteria.

**Table 7. Data Analysis Schedule\***

|  |  |  |
| --- | --- | --- |
| **Team #** | **Cycle 1**  **Week 3** | **Cycle 2**  **Week 3** |
| Team 1 | 12:30 | 12:30 |
| Team 2 | 12:45 | 12:45 |
| Team 3 | 1:00 | 1:00 |
| Team 4 | 1:15 | 1:15 |
| Team 5 | 1:30 | 1:30 |
| Team 6 | 1:45 | 1:45 |
| Team 7 | 2:00 | 2:00 |
| Team 8 | 2:15 | 2:15 |

**\*Please be prepared and present slightly ahead of your scheduled time so the transition between teams goes smoothly.**

**C. Written Report and Oral Presentation**

The team will meet with the instructor to submit the Written Report and make an Oral Presentation of their report. The presentation schedule is given in Table 8. Late reports will be penalized. Reports will be graded for technical content and writing. A 15 minute Oral Presentations in PowerPoint format will be made by the team. Approximately 10 minutes will be allotted for questions. See Appendix III and IV for grading criteria.

**Table 8. Oral Presentation Schedule\***

|  |  |  |
| --- | --- | --- |
| **Team #** | **Cycle 1**  **Week 6** | **Cycle 2**  **Week 6** |
| Team 1 | 12:30 | 12:30 |
| Team 2 | 1:00 | 1:00 |
| Team 3 | 1:30 | 1:30 |
| Team 4 | 2:00 | 2:00 |
| Team 5 | 2:30 | 2:30 |
| Team 6 | 3:00 | 3:00 |
| Team 7 | 3:30 | 3:30 |
| Team 8 | 4:00 | 4:00 |

**\*Please be prepared and present slightly ahead of your scheduled time so the transition between teams goes smoothly.**

**5. Social-Justice Statement**

“WVU is committed to social justice. I concur with that commitment and expect to maintain a positive learning environment based upon open communication, mutual respect, and nondiscrimination. WVU does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color or national origin. Any suggestions as to how to further such a positive and open environment in this class will be appreciated and given serious consideration. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Office of Disability Services (304-293-6700)”

**Appendix I: Pre‑Laboratory Report (50 points)**

Pre‑laboratory planning requires a review of the pre-lab memo and an inspection of the apparatus in the laboratory. All aspects of the experiment must be planned. The pre‑laboratory report should include, but is not necessarily limited to, the identity of the measured and controlled variables, methods of control and measurement, the number and range of data points, sources and (estimated) magnitude of error in measured variables, experimental procedure, and safety considerations.

One key to success in experimental work is to ask continually: *What am I looking for? Why am I measuring this? Does the measurement really answer any of my questions? What does the measurement tell me?* These questions may seem rather elementary, but they should be asked frequently throughout the progress of any experimental program.

Note that an experiment will not be permitted to be run until an acceptable pre-laboratory plan is approved.

## Pre-Laboratory Report Grading (50 points)

**A. Overall Objectives (5 points)**

Summarize the goals of the experiment, and your proposed approach to those goals.

**B. Details of Experimental Work (40 points)**

1. Outline the experiment and identify important process variables and measurements. Relate them briefly to important theoretical concepts.

2. Estimate the range of the more important process variables that you intend to cover in the experiment.

3. Estimate the source and magnitude of errors in the measured variables.

4. Summarize the safety considerations and outline emergency procedures.

**C. Appearance and Exposition (5 points)**

Report should have neat appearance and be free of grammatical errors.

**Appendix II: Data Analysis Review**

Quality data and correct data analysis are essential to the overall success of any laboratory experiment. ***An initial but complete analysis of the data*** provides a critical test of experimental and theoretical approach. It is at this point that problems with either can be identified and, if necessary, adjustments can be made. Once the experimental and theoretical approach have been validated, the remaining labs can be used to improve the quality of the data, assess reproducibility, and explore other issues relevant to the experiment.

**Deliverable: Excel file including two data sets, complete data analysis / calculations, and graphs of data and necessary calculations**

## Data Analysis Grading (50 points)

**A. Overall Objectives (10 points)**

Demonstrate an understanding of the experimental goals along with the data analysis methods and theory necessary to achieve these goals. Identify potential issues.

**B. Data Analysis (40 points)**

1. Excel table or graph of raw data.

3. Excel analysis of the data and associated plots.

4. Error analysis plan.

5. PowerPoint showing equations used in Excel calculations, values of parameters and physical constants.

6. An example calculation.

**Appendix III: Written Report**

**Written Report Grading (100 points)**

**Title Page (5 points)**

**Abstract (10 points)**

Complete / Concise

Clarity of thought

**Introduction (10 points)**

General background information

Motivation / Refined problem statement

Conditions and limitations

References cited and listed in reference section at end of document

**Theory (10 points)**

All needed equations

Logical order

All terms defined in text (not table)

All relevant fundamental principles given

References cited and listed in reference section at end of document

**Experimental Methods (20 points)**

Labeled figure (not photo) of apparatus

Apparatus and materials described

Use of apparatus / methodology / procedure described

Plan for analysis of the data using the theory

Plan for statistical analysis of the data / error

Hazards identified / remedial measures described

References cited and listed in reference section at end of document

**Results and Discussion (20 points)**

Results of measurements presented / tabular and graphical

Errors and statistical analysis of the data presented

Analysis of data using theory

Propagation of error

References cited and listed in reference section at end of document

**Conclusions and Recommendations (10 points)**

Complete / concise

Consistent with results

**Writing (10 points)**

Format followed

Organization of thoughts

Complete story told

Spelling

Grammar and punctuation

Length / level of detail appropriate

**Data / Calculations Appendix (5 points)**

Representative printout of Excel data worksheet

Columns / rows clearly labeled including units as needed

Calculations in each column explained as needed

**Appendix IV: Oral Report**

**Oral Report Grading (50 points)**

**Presentation (10 points)**

Organization logical / Format followed

Clear, uncomplicated sentences; absence of obscure and ambiguous statements

Spelling / Grammar (spoken and printed)

Figures and tables: properly sized; readable; conveying important information

Poised; non-frivolous and natural demeanor; adequate voice volume

**Technical Content (30 points):**

Data acquisition clearly explained

Data analysis clearly explained

Accuracy of results discussed

Comparison of results to outside sources

Conclusions / Recommendations

**Response to Questions (10 points)**

Knowledge of all aspects of the experiment

Technically sound and correct answers

Defends methods, procedures

**Appendix V: Sample Cover Page Information for Submitted Reports**

For Pre-laboratory Report:

|  |  |  |
| --- | --- | --- |
| *ChE 451: Pre- Laboratory Report* | | |
| *TEAM No.:* | | |
| Cycle No.: | **Experiment No.:** | **Date:** |
| Experiment Name: |  | |
| Submitted to: |  | |
| Team Members: | 1. | |
| 2. | |
| 3. | |
| 4. | |

For Written Report:

|  |  |  |
| --- | --- | --- |
| *ChE 451: Written Report* | | |
| *TEAM No.:* | | |
| Cycle No.: | **Experiment No.:** | **Date:** |
| Experiment Name: |  | |
| Submitted to: |  | |
| Team Members: | 1. | |
| 2. | |
| 3. | |
| 4. | |