Catalog Description
Design of laboratory experiments that demonstrate the principles of process measurement and instrumentation through the determination of thermodynamic properties, transport phenomena properties, and heat and mass transfer coefficients. Treatment of data to include regression techniques, calculation of measurement error, and statistical analysis of variance.

Program Educational Objectives Addressed in this Course
1. An ability to design and conduct experiments, as well as to analyze and interpret data.
2. An ability to function on multidisciplinary teams.
3. An ability to observe and recognize good laboratory safety practices.

Prerequisites: CHME 306 and CHME 311

Instructor: Dr. Daniel Gulino
Jett Hall 171 (southeast corner)
575-646-1559 (during office hours or to leave a message at other times) or 740-517-2389 (cell, no later than 9 p.m.)
gulino@nmsu.edu

Office hours: Tuesdays and Thursdays, 10:00 a.m. – 12:00 noon. Other times by appointment.

Teaching Assistant: Mai Zu (patrick.xuu@gmail.com)

Course Goal and Objectives
The goal of this course is to introduce students to practical skills needed to be able to apply the scientific and engineering concepts acquired in earlier coursework and to achieve the following:

• Organize and carry out experimental design and actual hands-on experiments
• Understand safety regulations and safe operation procedures in the Chemical Engineering laboratory
• Be able to analyze and interpret experimental data with theories learned in previous courses
• Write organized and cohesive technical and reports
• Organize and prepare standard operating procedures
• Work effectively in a team environment
• Prepare and present technical works and answer questions.
Experiments
The following experiments will be carried out in Spring 2015. Please refer to this list for the letter corresponding to each experiment as that is how they will be referred to in the schedule.

A. Analysis of Centrifugal Pumps, Valve Coefficients, and Piping
B. Linear and Radial Heat Conduction
C. Double-Pipe Heat Exchanger
D. Vapor/Liquid Equilibrium

All students will work in groups and will perform every experiment.

Groups
Group assignments and the course schedule will be revealed and discussed at the first class meeting and will be posted on Canvas after that date. The goal is to keep group sizes to no more than three, but some may have to be four in size to accommodate all students.

Report Policy
Written Reports: Full details about the experimental reports you will write are attached. To summarize, each group will submit a written report for each experiment. Reports will be due no later than the start of class one week after you finish the experiment and must be submitted electronically to the instructor in Microsoft Word (.doc or .docx) format through Canvas or via email. See the attached schedule for details.

Oral Reports: Each team will make one oral presentation during the last class week of semester as noted on the schedule. Your group’s presentation will be on the experiment your group performs last on the schedule. All team members must speak, and it will be up to the team to determine who talks about what aspect of the experiment. The entire presentation should be no more than about 20 to 25 minutes in length.

Performance Evaluation
Grades for each experiment and for the course as a whole are determined as shown below. Note that, in addition to the more tangible, quantitative, pre-lab, and report portions of your grade, there are also less tangible, semi-quantitative portions which include safety and teamwork. Your attitude toward and display of good safety practices will be observed over the entire semester and a number assigned to you accordingly. Note that this is a negative grade assignment in that you all begin the semester with the full complement of safety “points,” and points will be deducted based on your performance in the lab. If you display and encourage nothing but wonderful safety practices, you will receive the maximum number of points. Anything less, and points will be deducted at the instructor’s discretion. The same kinds of observations will be made regarding the difficulty-to-quantify concept of “teamwork.”

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<th>Per Experiment/Report</th>
<th>Total for Course</th>
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<tr>
<td>Pre-Lab</td>
<td>20 pts</td>
<td>80 pts</td>
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<td>400</td>
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<td>Oral Presentation</td>
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<td>Safety</td>
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<td>Teamwork</td>
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The instructor will grade your reports and will consider both technical content and accuracy as well as writing quality. This means proper English in terms of tense (always past), person (always third), sentence construction, and more. While you will be working in groups, you are submitting a single report, and it must read as though it was written by one person, even if the various parts of it were prepared by different individuals. Your group might have done the best work ever on a particular experiment, but if you cannot communicate this effectively, you might as well not have done it at all.

The instructor will also grade your oral presentation and will look for a concise, well-organized presentation with slides that are well-designed and formatted, contain no spelling, grammatical, etc. errors, and contain no more information than is necessary to get the point across. The oral report will be graded more on the quality of the presentation than on the technical content as the technical content will have been graded in the written version of the report you will have submitted previously. Your final course grade will be awarded according to the following distribution: 90-100 A, 80-89 B, 70-79 C, 60-69 D, <60 F.

CHME Common Syllabus Addendum
The syllabus addendum common to all CHME courses is incorporated herein by reference and may be viewed at http://chme.nmsu.edu/academics/syllabi/chme-common-syllabus-addendum/. The Addendum covers CHME Announcements, Attendance Policy, Student Accessibility Services (disability accommodations), Misconduct, Re-grades, Student Work Products, Communication, Video Surveillance, Computer Resources, Etiquette, Firearms, and Intervention. You are strongly encouraged to read it.

Detailed Laboratory and Report Instructions

You will participate in and perform a total of four experiments in this course. You will work in groups, with each group performing a different experiment over a one-week (two lab meeting) period on a rotating basis. Because there are more groups than there are experiments, not every group will be in the laboratory every class meeting.

A written pre-lab from your group will be due to the instructor no later than 11 a.m. on the first day on which you are scheduled to perform that experiment. The pre-lab must be submitted electronically as a Microsoft Word document (.doc or .docx) through Canvas or as an email attachment directly to the instructor.

As far as the reports themselves, your group will hand in a single document with the following sections: Summary, Introduction, Procedure, Presentation of Results, Discussion, Analysis of Error, and Reference/Appendix sections. These sections are discussed below. For the experiment for which you deliver an oral report, a written report is still required. The oral report will be graded separately and will focus more on the quality and organization of the presentation and less on the technical content as that will have been examined when the written report is graded.

Attendance is required at all experiment meetings. Failure to attend without a valid excuse will result in a zero for that person for that experiment. There is no such thing as “getting the data” from someone else in your group or anyone else.

Proper attire for the lab includes closed-toe shoes, long pants, and shirts with long sleeves. If you do not wear a long-sleeve shirt to the lab, you can borrow a laboratory smock for the duration of the lab. No loose, dangling clothing is allowed. Eye protection is required at all times, and safety goggles may be checked out in the lab for use that day.
Instructions for each of the experiments as well as equipment operating manuals where appropriate are downloadable and printable from Canvas.

The specifics of the lab reports are discussed below. All lab reports, once graded, become the property of the Department of Chemical and Materials Engineering. Reports will be graded for both technical content and writing style (English usage, grammar, spelling, etc.). The grade for each section, as well as the report as a whole, will incorporate both the technical and grammatical aspects of the writing. Comments will be placed in your report using the “review” capabilities of Microsoft Word, and the graded, commented-on report will be returned to you electronically.

Laboratory Rules

No food or drink is permitted in the laboratory at any time. Deposit all trash in the receptacles near the door upon entering the laboratory.

SAFETY is each person's full-time responsibility. Plan your work before starting. Always exercise extreme care with chemicals which may be poisonous, corrosive, flammable, and/or explosive. Be careful with glassware. Be careful when you are near or when you are using powered equipment. Several of the experiments require heating of materials, so there will potentially be hot surfaces, although the experiments are designed to minimize your exposure to this. There may be hot plates in use, so be careful around those.

Cleanliness is mandatory in the laboratory. Equipment is to be cleaned and the lab benches straightened up after use. Any tools used should be put away. Make sure all equipment connected to electrical power is turned off.

Report Format and Content

Comments for All Reports

Always write with your reader in mind. Try to put yourself in their position. How is he/she going to interpret what you write? If it is clumsy to you as you write it, it will be more so to a reader. Your audience for the lab and memo reports should be your boss's boss, i.e., a person with a solid general understanding of the subject matter, but not knowledgeable as to the specifics of your project.

All work must be proofread. Spelling and grammatical errors reflect badly on the work in general. A slick presentation cannot cover for shoddy work, but a poor presentation can ruin good work. A suggestion is to let some other knowledgeable party read it. If they have trouble understanding anything, you can be sure that the instructor will, too.

No formal report binder is required. However, the first page of each report should include your group number, the names of the group members in alphabetical order by surname, the name of the experiment, the number of the course, the date(s) the experiment was(were) performed, and the date the report was due. Points will be deducted if any of this information is missing. How you arrange this information on the page is up to you. But be sure it’s all there, and be neat and organized.
**Pre-labs**

Pre-labs are to be submitted electronically. As noted earlier, your group will turn in a single pre-lab to the instructor by 11 a.m. on the first day that you will work on that experiment. As to the content of the pre-lab, it should be a brief (no more than a page or two, 1.5- or double-spaced) description of the experiment to be performed, the equipment to be used, the raw data to be collected, and how that data will be analyzed.

**Lab Report**

For the most part, lab reports should be 1.5- or double-spaced. Lab reports will contain the following sections: Summary (typed single-spaced), Introduction, Procedure, Presentation of Results, Discussion, Analysis of Error, and References/Appendix. The individual sections are discussed and their weighting in the final report grade are given below. The grade for each section will be based on both technical content and English/grammar/spelling.

**Summary (25% of report grade)** – The Summary should be a concise (no more than one page—I will take off points if it exceeds one page!—typed single-spaced), overall description of the experiment. It should contain a clear, specific objective statement, the major aspects of the procedure (but NOT a step-by-step description), key results expressed quantitatively, and the conclusions drawn from the study. It should be quantitative to the extent possible. The goal should be to write a Summary which could be removed from the report and an informed reader could still understand what you did, how you did it, what you found, and what it means. If students have trouble with writing a good Summary, it is usually because they include too much procedural detail and not enough quantitative results. Procedural detail should comprise no more than one-quarter of your summary.

**Introduction/Objective Statement (5% of report grade)** – Describe briefly the type of information to be obtained in the experiment, who might want such information, and why they would want it. Include a statement of the objective of the experiment. Remember, the objective is never “to teach the student how to operate such-and-such equipment” or “to familiarize the student with the concept of such-and-such.” Rather, the objective is always technical in nature. “The objective is to measure the effect of pressure on the boiling point of mineral oil” or “the objective is to measure the thermal conductivity of polypropylene” This section should be no more than a page or two.

**Procedure (15% of report grade)** – Describe, in the PAST tense, and in THIRD person, specifically what you did, giving all details, specific measurements you made, and specific ways in which your data was processed and interpreted. In short, from the Procedure section only, one should be able to repeat exactly what you did down to the crossing of t’s and the dotting of i’s. Do not refer to other sections of the report, the lab manual, and so forth. Do not bother to describe how to perform standard types of measurements. For example, you can state simply “temperature was measured with a thermocouple” and leave it at that instead of going into detail on how the thermocouple works or how it connected. This is assumed to be standard knowledge.

**Presentation of Results (15%)** – Just as its name implies, this section is the actual graphs and tables used to present the information you obtained. Be careful to distinguish between data and results. Data is (are) the numbers you read off of a dial, a gauge, a digital readout, a computer screen, etc. Results are what you did with that data presented in some logical way (graphically,
tabularly, etc.). What will be looked for is the effectiveness of the presentation in terms of content and clarity. Give some thought to how best to present the information. Can graphs be combined for a more effective comparison? Will cross-plotting help? There is nothing wrong with the same information appearing on more than one graph.

On the other hand, don’t overdo it with graphs. For example, don’t make a bar chart if a simple table of data would be as effective.

To the extent possible, the results should stand alone. This means all relevant information should appear in the title of the graph, in the legend, or on the graph itself. If there is error associated with any measurement, this should be indicated in both the raw data and as error bars on the graphs.

Discussion (20%) – The Discussion section should present all relevant information concerning the experiment. It should contain discussions of the results and their significance. It needs to be more than a rewriting of the results in paragraph form. A key topic is, were the results as you expected? Reinforce your claims by comparing them to the literature. Procedure should be discussed only where it is relevant to analysis of the results. It is very important that your discussion be quantitative to the extent possible. Feel free to add section headings within the Discussion if you believe that they would help the organization. Also, remember that the Discussion section should be more than what was presented in the Summary section. The summary presents a quick, almost bulletized snapshot of the experiment performed and the pertinent results. The Discussion presents the complete picture.

Analysis of Error (15%) – Students generally love to point out all the things that are wrong with an experiment (old, worn equipment, unstable temperatures, poor quality materials, fellow students who botch a measurement, mix samples up, or drop one on the floor, etc.). Well, here’s your chance to discuss this. But just listing the possible sources of error is not enough.

First, you should discuss the magnitude of the error. An older piece of equipment won’t necessarily be a less accurate one if it’s been properly calibrated. By the same token, students often write that the readings from newer measurement device of some type must be more accurate because they are newer and because the readouts are digital. Pretty red lights don’t create accuracy. If there is a source of error, decide if it’s a large error or a small one. I’ll leave up to you to decide where to draw the line between the two (but, to me, a small error is ±5%, and a large one is ±50%).

Second, you should distinguish between errors that could be made smaller if you only had the time do the experiment more carefully and errors that are inherent in the procedure and could not be made smaller no matter how carefully you perform the experiment.

Also, be sure to distinguish between the words “accuracy” and “precision.” These words get tossed around all the time in discussions of error, but they do have specific meanings, and they are often misused. “Accuracy” is a measure of how close each reading is to the true value of what you are trying to measure. Therefore, you may not be able to say anything about the accuracy of the readings in a particular experiment if you don’t know what the true value is.

“Precision” is a measure of how well a number of measurements of the same property agree with each other. Since you will want to make several repeat measurements of whatever property is of interest, this is something you should be able to discuss at great length.

Also, remember that the two are not related. It’s possible to make a series of measurements of something and have them vary all over the place. You would say that the measurements exhibited poor precision. But if their average is close to the true value of the property being measured, you could say that they exhibit good accuracy.
On the other hand, if you make a series of measurements that are all near each other, you could say that they exhibit good precision. However, if these readings are all significantly different from the true value, you must also say that they exhibit poor accuracy. The best situation, obviously, is to have both good precision and good accuracy.

References/Appendix (5%) – References are literature sources (the experiment and equipment manuals, manual, textbooks, library holdings, web sites, etc.) you consulted in the interpretation and writing of your report. The Appendix should contain any information relevant to the report but not of sufficient importance to be included elsewhere. The Appendix could include sample calculations (including error calculations), calibration curves, and anything else you feel is needed for an understanding of the report. These pages should be properly and sequentially page numbered so that you may refer to them as needed.

Rubric for Grading CHE 322L Reports

Below is a general rubric that the instructor will use for grading the regular lab reports, and it gives a good indication of the types of things that will be looked for. Comments about your report will be attached using the Review feature of Word. All of this will use this in conjunction with the weightings of the various sections as described above in determining a grade for each section and each report.

If you have any questions concerning the content of these sections in terms of a specific experiment, please ask.

The following elements will be of particular interest in your reports. When an element is not present, appropriate comments will be made on your report. In short, the list below describes what is looked for when the report is graded.

1. The experimental procedure is explained. The level of explanation is appropriate for a reader who knows or has access to general information such as how to read a thermometer or operate a viscometer and who is uninterested in information which is not needed to understand the results of the experiments.

2. The required results are included in the main body of the report, not buried in the Appendix. Numerical values are associated with appropriate units and reported with an appropriate number of digits (significant figures).

3. Noted trends or conclusions are correct, quantitative when possible, and based on or compared to the relevant underlying science and engineering principles. Words like “accurate,” “reliable,” “good,” “bad,” and the like (which are generally meaningless by themselves) are not used unless the meaning is explained. Conclusions are present when the results warrant them. Statements can be substantiated with facts.

4. Tables and figures have the required titles, captions, labels, units, and orientation. Decimal values are aligned in tables. Data points are identifiable on figures. Curves used to fit data
are appropriate. Error bars are present when appropriate, and what they represent is explained. Each table or figure is referenced in the text and appears shortly after the first reference in the text.

5. Correct technical terminology is used. Sentences and paragraphs are logical and meaningful. Overly colorful, conversational, or vague language is not present. The report is concise and not repetitious.

6. Correct grammar, spelling, and style elements are used. Style elements include use of past tense to describe experiments completed, present tense to describe results given in the report (future tense is nowhere to be found in the document), and the use of third person. Paragraph development also fits into this category along with proper capitalization.

7. Citations and reference lists follow accepted styles and are complete and therefore usable.

8. Insights or professionalism beyond that expected from a junior-level student are present. This is an intangible category included to reward extra effort or ability.

**General Comments About the Experiments**

The experiments vary in the degree of guidance provided in the manuals. In some cases, you will be given almost step-by-step instructions, and in others you will be given little more that a statement of the objective or objectives and some instruction on the operation of the equipment. Manuals provided by the manufacturer, where available, will be provided at the bench as well as on Canvas in electronic format.

It will up to you as part of the pre-lab process and of the performance of the experiment itself to determine the appropriate procedure, conditions to be varied, number of repetitions made, and analysis of the results. One of the primary objectives of this course is to give you experience in the design and performance of experiments, and even those with more detailed instructions still require significant planning from you. You won’t gain much experience in this if the procedures are spelled out for you in a more or less cookbook fashion. As always, if you ever have questions, please ask!