

AC 2007-476: USING A MECHANICAL ENGINEERING LABORATORY COURSE FOR ASSESSMENT

Kenneth Van Treuren, Baylor University

Ken Van Treuren is a Professor in the Department of Mechanical Engineering at Baylor University. He received his B. S. in Aeronautical Engineering from the USAF Academy in Colorado Springs, Colorado and his M. S. in Engineering from Princeton University in Princeton, New Jersey. After serving as USAF pilot in KC-135 and KC-10 aircraft, he completed his DPhil in Engineering Sciences at the University of Oxford, United Kingdom and returned to the USAF Academy to teach heat transfer and propulsion systems. At Baylor University, he teaches courses in laboratory techniques, fluid mechanics, energy systems, aeronautics, and propulsion systems, as well as freshman engineering. Research interests include experimental convective heat transfer as applied to HVAC and gas turbine systems.

Using a Mechanical Engineering Laboratory Course for Assessment

Abstract

This paper characterizes the mechanical engineering laboratory course taught at Baylor University and how this course is used to support ABET outcomes b) design and conduct experiments, as well as analyze and interpret data, g) communicate effectively, and k) use the techniques, skills and modern engineering tools necessary for engineering practice. As a course typically taken in the last semester of their senior year, students review topics taught in the fluids/thermodynamics/heat transfer stem of the mechanical engineering program, as well as learn new experimental techniques. For the first half of the course, each week consists of a one hour lecture, a three hour practical measurement/demonstration session (often involving calibration techniques) and a three hour laboratory usually involving the measurement techniques from that week's measurement/demonstration session. The last half of the course is a laboratory project, accomplished in teams of two or three. For the laboratory project, the students initially do a test plan written report and presentation early in the course to get the necessary background for the project. This enables the students to purchase required materials and begin fabrication, if necessary, for the final project. The course ends with a final project report and a formal final briefing. While the workload on the part of the professor is demanding, the course was highly praised during the last two ABET accreditation visits. Student feedback from industry also confirms the usefulness of such a course. The assessment tools used in this course will be discussed in the context of the three ABET outcomes to be measured.

Introduction

Assessment is an important process that must be accomplished for all mechanical engineering programs. Many programs directly use ABET Criterion a-k to assess outcomes and identify where these outcomes are found in their programs. Baylor University adopted the ABET outcomes in preparation for its recent ABET assessment. Using the ABET outcomes, the faculty examined their courses for current assessment tools which supported the a-k outcomes. It was found that most of the senior level courses, especially the senior design and the senior mechanical laboratory course, could be used to satisfy nearly all of the outcomes. It was natural that senior level courses should exhibit the outcomes because these types of courses show how seniors demonstrate required skills or abilities. The current course, EGR 4335 Mechanical Engineering Laboratory (ME Lab), specifically supported five of the 14 outcomes: a, b, e, g, and k. The assessment tools comprised prelab homework, exams, an experimental design project, written reports, oral presentations and team/peer evaluation. The senior capstone design course, taken in addition to ME Lab, accounted for another seven outcomes. It was decided by the faculty that one or two courses are not sufficient to demonstrate the necessary assessment of the program outcomes. There were several outcomes, though, which made more sense to be assessed by a laboratory course. For instance, all accredited engineering programs must have a component of experimental design in their curriculum. ABET Criterion 3b states "Engineering programs must demonstrate that their graduates have an ability to design and conduct experiments, as well as to analyze and interpret data¹." How does one achieve such a desirable

end? Lecture format courses have been used to teach experimental techniques but these courses may not be the best way to achieve the desired result.^{2,3} Most universities have blended lectures with a more hands on approach.⁴⁻⁶ At Baylor University, mechanical engineering majors have two significant laboratory experiences. The first is a materials laboratory course in the spring of their junior year that covers the basics of materials testing; hardness, stress and strain. The course is a three credit hour course with two hours of lecture and three hours of lab. Students are exposed to collecting data and writing lab reports, but at this level, they do not do traditional error analysis. In the current curriculum, detailed laboratory measurements and error analysis are accomplished in the spring of the senior year when students are scheduled to take ME Lab. While the materials lab is the culmination of the materials stem in the mechanical engineering curriculum, ME Lab is the culmination of the fluids/thermodynamics/heat transfer track. It is also considered the capstone course in experimental design and measurement. ME Lab figures prominently in the following ABET Criterion 3 outcomes¹:

- b. an ability to design and conduct experiments, as well as to analyze and interpret data
- g. an ability to communicate effectively
- k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Once it was decided that these three outcomes would be supported by the course, the faculty then defined what was meant by each of the outcomes so that assessment could be done. The explanations are given below:

a. design and conduct experiments, as well as to analyze and interpret data – not every experimental activity will have design, conduct, analyze and interpret.

1. Experiments done in teams of two or more will attempt to determine which students contributed to what parts of the laboratory experiments. The recommendation is to use an executive summary that each student writes and sends to the instructor. The student outlines his or her contribution to the experiment. This may result in different grades given to the team members on experiments based upon the executive summary and the professor's observations.
2. Individual laboratory experimental reports are accomplished in ME Lab which will cover "analyze and interpret". Team project will include a major emphasis on design.
3. Design is addressed on a small scale in Materials and on a larger scale in ME Lab. Again, design is done in teams and some determination is needed as to the contribution of each student in this area.

b. communicate effectively – Written, graphical, and oral

1. ME Lab has individually written laboratories
2. ME Lab has a final project done in teams of two. To assess individual contributions, each student will individually submit to the professor an assessment of their contributions to include the areas they accomplished. Therefore, both oral and written work can be evaluated individually.

k. use the techniques, skills, and modern engineering tools necessary for engineering practice – Tools are defined as both software and hardware. Tools can also be thought of as equations which are used to solve engineering problems. Techniques are solution methods using a knowledge of physics and engineering principles which allow a successful solution to a problem. Skills are a set of abilities which are used to find a solution to a problem. These can be such skills as brainstorming (creativity) to application of tools (using software correctly and appropriately).

1. This outcome can be assessed by a number of courses.
2. A successful grade on a project or problem which incorporates this outcome will be used as the assessment.

The skills learned in ME Lab are a major part of the formation of laboratory skills in a student's engineering development at Baylor University. As such, students are exposed to many different techniques of measurement, data collection, and are required to do develop communication skills, both written and oral. This paper briefly outlines the course as it was taught in spring 2006. It will discuss grading criteria, skill development, and then highlight some of the assessment processes in place.

ME Lab Course Organization

ME Lab is a three credit hour course taught as one hour of lecture and six hours of laboratory. Its course description is:

“Measurement of fluid flow, heat transfer, power, and other properties of mechanical equipment. Design of experiments, selection and use of data acquisition systems, data reporting, and presentation.”⁷

Course objectives state⁸:

1. Learn the important tools and concepts associated with work in a mechanical laboratory including; experimental methods and techniques, data-analysis techniques, engineering measurement systems, and test equipment/facilities.
2. Learn how to plan and conduct an experiment
3. Learn how to evaluate experimental data
4. Learn how to present your results, in both written and oral forms

Because of the desire to give students more hands on experience, two sections of the course are offered with typically 8 to 10 students per section. The course is only taught in the spring semester due to faculty availability. The one hour lecture is given on Tuesday mornings. To ease professor workload, both sections are scheduled for the same lecture period. The labs are given on Tuesday and Thursday afternoons. While this would normally require six lab hours per lab day for the professor, the lab periods are scheduled with a one-hour overlap in the middle of the lab periods. For instance, the first section would meet from 1 to 4 pm but only spend from 1 to 3 pm in the laboratory. At 3 pm the second section would arrive and would be scheduled from 3 to 6 pm. Actual laboratory time for second section would be from 3 to 5 pm. This “extra” hour is theoretically used by the students for reducing data outside the classroom. Students are

not required to work in the lab or on the computer during this hour. They are treated as responsible adults and must get the lab report done by the due date, however, the professor is available during this hour should they need help.

The course content is basically divided into two parts over the 15 week semester: eight out of the first 10 weeks are devoted to developing laboratory and communication skills and the remaining seven weeks are devoted to developing and accomplishing the experimental project.

Grading Criteria

The course assessment is divided between individual (65 % of total course) and team (35 % of course total) exercises. Grading for the course is comprised of the following:

Lab Reports (7) (Individual)	30 %
Pre-labs (Individual)	10 %
Project Test Plan (Team)	10 %
Final Project (Team)	25 %
Midterm (Individual)	20 %
Professor Points (Individual)	5 %

Lab reports account for a significant portion of the final grade. The lab reports are written on a series of seven predetermined laboratories that the students accomplish in the first half of the course. The data for each lab report are taken as a group during the Thursday lab period however; the written lab report, to include data reduction, is accomplished individually. The report format used is a memo format developed at Baylor University (see appendix A) which is strictly adhered to, much like a prescribed format for publication at any conference or in any journal. This is usually the students' first exposure to such a requirement and it takes several iterations for them to get the report format correct. Individual written work allows for assessment of student written communication skills. Overall, lab grades are tracked for each student as well as the "General" presentation grade which includes format, neatness, spelling and grammar. Grading individual lab reports every week is time consuming. Lab reports are due on the following Tuesday during the lecture hour. Experience shows that from Thursday afternoon until Tuesday morning is sufficient time for students to accomplish quality work. Initially, some students would wait until Monday to start the lab report and receive low grades. Eventually students realize that must start earlier for a quality product.

For each laboratory, a prelab homework exercise is required and is due at the beginning of the Thursday laboratory period. This prelab is a short introduction to the lab material which may include questions on physical concepts or contain sample data similar to what might be taken that week during the Thursday lab period. The main purpose of the prelab is to introduce the calculations required to reduce the lab data for that week. The experiments conducted involve fundamental physical principles which the students are expected to know or to review on their own. A laboratory handout is given each week, well before the Thursday laboratory period, which outlines the fundamental equations as a review. Little time is available for instruction in fluid mechanics, thermodynamics or heat transfer during the course. During the Tuesday lecture, the measurement technique to be emphasized is discussed using PowerPoint slides with diagrams

and pictures of equipment. If the equipment is portable, it is sometimes brought into the classroom for familiarization.

The Project Test Plan is accomplished during the fourth and fifth weeks of the semester. Prior to this, the professor develops a list of possible experiments from which the students, in teams of two (three if there is an odd number of students in the section), can select for their semester project. The spring 2006 semester had 17 possible choices. Students are also free to develop their own experiment or to support an external agency such as the NASA Texas Space Grant Consortium. These two weeks, occurring early in the semester, are dedicated to defining the project as well as detailing final expectations. In the third week of the course, students select teams and are given a form to, first, list the team members, and second, list their top three project choices in rank order. Students can work with any student in their own section. The professor does not select teams. The professor collects the forms and seeks to match teams with projects based on their requests and their skill sets (i.e. Labview, Matlab, strength in a particular academic area, etc.). The lecture during the fourth week is devoted to designing experiments. The lecture during the fifth week is on report writing. During the Tuesday laboratory period of the fourth week, the student teams meet with the professor for approximately 15 minutes to further define their project. It is a time for the student to ask questions about requirements and project direction. The professor develops the vision for the project with the students. Lab periods for the fourth and fifth week are then used for researching the topic. Test plan reports are due at the beginning of the sixth week during the lecture. These reports follow a prescribed format which has some similarity with the ASME standard used for journal submissions^{9,10}. During the laboratory period of the fifth week, the student teams make a 10 minute presentation to the other members of the section and interested faculty. Five minutes of questions follow. The written report is worth 5 % of the final grade as is the presentation. Assessment of team projects will be discussed later in the paper.

The Final Project report is due on the last day of classes. During this class, students give a 15 minute formal presentation over their topic. Presentation sessions are open to the public. Other professors and students not in the course are invited to attend. The written project report is worth 15 % of the grade and the presentation is worth 10 %.

The midterm exam is, in reality, a final exam on first half of the course. It is a written exam accomplished during a two hour exam period. The exam consists of two parts, the first being a closed book portion testing knowledge of experimental techniques and vocabulary. The second part of the exam is given upon completion of the closed book portion of the examination. This part is open book, containing such things as uncertainty analysis problems, thermocouple laws, velocity measurement and data acquisition.

Lastly, professor points are points assigned by the professor based on class participation, laboratory participation, experimental laboratory notebook maintenance, completion of draft paper, etc. At 5 % of the final grade, it can make the difference if someone is close to the next higher letter grade at the end of the course.

First Part – Developing Laboratory and Communication Skills/Assessment

As previously mentioned, eight of the first ten weeks are devoted to learning measurement techniques and using laboratory equipment. The current syllabus for this portion of the course is as follows:

Table 1 – First ten weeks of EGR 4335, ME Lab

Week	Tuesday Lecture	Tuesday Lab	Thursday Lab
1	Introduction	Error Analysis	Data Reduction
2	Pressure Measurement	Calibrate Transducer	Orifice Lab
3	Fluid Flow Measurement	Calibrate Hot-wire	Cylinder Drag Lab
4	Design of Experiments	Project Plan Meetings	Work Session
5	Report Writing	Work Session	Plan Presentations
6	Fluid Flow Measurement	Boundary Layer Measurement	Weir Lab
7	Temperature Measurement	Thermocouple Demonstration	Heat Exchanger Lab
8	Electrical Measurement	Filtering Demonstration	HVAC Fluid Flowrate Lab
9	Force, Torque and Strain	Strain gage/ bridge circuit demo	Heat Pump Lab
10	DAQ/Processing	DAQ Demo	Work session for final project

For the first half of the course, each week consists of a one hour lecture, a three hour practical measurement/demonstration session (most often involving some sort of calibration) and a three hour laboratory usually using the measurement techniques talked about in the previous measurement/demonstration session. For example, on week three, the students are taught in the lecture about fluid flow measurement to include the principles of hot-wire anemometer. That afternoon the students calibrate a hot-wire probe using a pitot-static tube with a calibration quality pressure transducer and a micromanometer as the calibration source. On the Thursday lab session, the students use that calibration to measure the downstream wake of cylinder and calculate drag using a momentum deficit technique. As another example, week seven is dedicated to temperature measurement. The lecture covers the use of various temperature measurement devices from thermometers to thermocouples to liquid crystals. The demonstration session has various stations set up for students to experience calibration of a handheld digital thermometer using a digital calibrated source and both boiling water and a 0°C water/ice slurry. Various types of thermocouples are available for students to make measurements of voltage and to convert voltages to temperature using the tables. Zero reference junctions are displayed and used. Integration with a data acquisitions system is also demonstrated. The experiment for that week is to characterize the performance of a shell and tube heat exchanger using temperature measurements obtained with a data acquisition system.

Assessment in a course that has teams presents a challenge. For this reason, 65 % of the graded items in the course are accomplished individually. Prelabs are similar in concept to homework and are very straightforward to grade. Again, this is an individual grade. Lab reports are graded according to a guide which is given to each student on the first day of class (see Appendix A). The grading sheet describes what is to be included in each lab report section. Often the students do not refer to this guide and waste valuable points by not including all that is required. While the entire lab is about communicating data and results, ten percent of the lab grade specifically assesses written communication and is devoted to format, neatness, spelling and grammar. Below is a table representing the grades for labs and the ten percent grades for the written communication. The categories decided by the department were: Superior – greater than 90%, Excellent - 80 to 90 %, Acceptable – 70 to 80 %, Unacceptable – below 70 %. As can be seen, most students are acceptable or above. While there were unacceptable grades for students, most students were able to show improvement. There were other writing samples evaluated, such as written reports, which were acceptable.

Table 2 Grades for Individual Laboratory Reports (17 Students)

	Lab Score		Lab Written Score	
	Number of Students	Percentage	Number of Students	Percentage
Superior	10	58.8	2	11.8
Excellent	6	35.3	8	47.1
Acceptable	0	0	5	17.6
Unacceptable	1	5.9	2	11.8

Participation in class and in the lab exercises are noted by the professor. While the Tuesday lab period is an interactive demonstration, it has no formal grade but it does have deliverables, for instance, a calibration graph of a pressure transducer. Notes are made by the professor for positive traits, group leadership and how well the student interacts with other students. This assessment becomes part of the 5 % Professor Points. In the Thursday lab period students are collecting data for their lab write-up. Students are required to have a spreadsheet/data sheet and will be graded on completeness of the sheet when the lab is turned in. In the Thursday lab, students have the laboratory handout and are not necessarily told how to complete the lab. Decisions on data points and number of samples must be made by the group. Observations are made by the professor as to which students are leaders for the lab period.

Group work begins during week four. At this time the student groups are beginning to research their chosen project. The dilemma for this portion of the course is how to assess individual contributions for the project. To address this dilemma, students attach a cover letter to the Test Plan Report detailing the contributions of each team member to the overall project. Grades can then be assigned individually; however, the grades may in actual fact be the same for each team member. During the project presentations, the professor assesses each team member individually (See Appendix B). Students are also asked to review and critique the presentations of other teams (See Appendix C). Students put their names on their critique sheets and these are collected at the end of the presentations. The individual student responses to the presentations

are part of the Professor Points. A student who does not accomplish the evaluation in a serious manner will lose points on the final grade. All the critiques are gathered, compiled, and type written comments are given to each student/team. Feedback to the presenters is important for their improvement. The Test Plan Report is evaluated using the form in Appendix D. (Report evaluation forms used for reports were modified from those used at the author's previous institution.) The written project reports are graded and individual grades can be adjusted based on their contribution to the report. Handouts for the Test Plan Presentation and Report are given to the students so they are aware of what is required for each section of the report. ASME writing standards are used where applicable and a writing guide is given to each student to help them understand what is required.

Lastly, an exam is given to evaluate knowledge gained from the first part of the course. Statistics are done on the exam scores by question. Each question directly supports one of the learning objectives in the course. Each question can also support outcomes of the ABET Criterion 3. These results are reviewed at the end of the course to determine if changes need to be made in the presentation of the course lecture material or practical laboratories. Table 3 shows how the exam supports assessment of the course objectives.

Table 3 Exam Support of Course Objectives (17 Students)

	Objective 1		Objective 2		Objective 3		Objective 4	
	Number of Students	%	Number of Students	%	Number of Students	%	Number of Students	%
Superior	5	29.4	11	64.7	9	52.9	6	35.3
Excellent	4	23.5	0	0.0	3	17.6	5	29.4
Acceptable	7	41.2	4	23.5	2	11.8	4	23.5
Unacceptable	1	5.9	2	11.8	3	17.6	2	11.8

Second Part – Applying Laboratory and Communication Skills/Assessment

During the last part of the course the students are working on their assigned project. It is during this part that students learn to “design and conduct an experiment, as well as to analyze and interpret data,”¹ ABET Criterion b. While they students have conducted experiments and reported results in the first half of the course, it is in the second half that they have to deal with an ill-defined problem. During this half of the course, the lecture hour is used for students to meet with their professor and report weekly progress. Students are asked to have a list of accomplishments from the previous week and set goals for the next week. Problem areas or areas where the professor could be of help are discussed. Lab periods are work sessions which allow the student teams to have a time in their busy schedule where they can work without schedule conflicts. The professor is available during these times for questions. Students enjoy this self paced work environment; however, the weekly meetings do provide accountability. They are required to keep one lab notebook per team and these are evaluated during the weekly meetings. A draft of the final report is due one week prior to the final project due date and will be critiqued without a grade. This gives the students an opportunity for improving their final report. Students who do not turn in substantial drafts generally have poorer quality final reports.

Detailed requirements are given to the students for the final presentation and report. This is a formal presentation and report which translates to business attire for the presentation and a complete report with abstract, table of contents, nomenclature, lists of figures and tables, etc. Fifteen percent of the final project grade is given to spelling, organization and grammar. The grade for the entire report is an indication of the team's ability to communicate difficult concepts. Again, with the final report the student team turns in an executive summary detailing what the team members contributed and may be used to adjust the final project grade. Individual peer assessment is done by private e-mail at the end of the course. For the presentation, students are graded individually. By the time they finish the final project, the students have successfully learned how to communicate effectively, ABET Criterion g. Throughout the course students have been demonstrating the techniques, skills, and modern engineering tools that are used in engineering. Students may be working in teams, or making presentations, or communicating through the written word, or using tools such as Excel, Matlab, Labview, or using laboratory equipments such as a hot-wire anemometer, manometer, pressure transducers, temperature sensing devices and data acquisition systems. All in all, the students have a very extensive laboratory experience and end the course feeling confident about working in a laboratory.

Reflections on the Course

The ME Lab course is a very time intensive course for both professor and student. For the first half of the course, students are asked to write a lab report each week and they often feel this is excessive. Because of the individual nature of assessment, it is important that each student be evaluated on their written communication ability. At the beginning of the course student writing skill levels are varied however, by the end of the course marked improvement is shown. Students begin to have confidence in their abilities. These communication skills are often not appreciated until the student enters the workplace. Several student comments sum up the experience:

“I learned more in ME Lab than I ever did in the tech writing course we have to take as engineers. I wanted to tell you thanks for all of your hard work because it has really helped.”

“Recently I have been working on a report for a project and it reminds me of ME Lab. It really is very similar and I think they have been pleasantly surprised with my writing and proof reading skills. And of course I know how to make all the spread sheets and documents look good. It is a lot like the report we wrote at the end of the semester for the engine. It feels like home!! So, thanks for all you taught us because I'm already using it. And, something else I learned, documentation on your work is a very valuable thing. We worked on a project before this and I felt like I was on the phone all the time asking why someone had done something or where they got their information. It is good to come in knowing that things need to be uniform and documented, especially when working with a team.”

The course was also highlighted in the two past ABET accreditation visits as a course which “offers a wide array of practical experiments while integrating uncertainty analysis and design of experiments content.” Clearly, the course fulfills its responsibilities and has a definite impact on the students.

Future of ME Lab

While the course is fulfilling its purpose, a concern of the author is the lateness in which it occurs in the curriculum. A student on the four year traditional track must then take ME Lab and the senior capstone design course concurrently. This creates time pressures that stretch the students. Each year there are a number of students who opt to take ME Lab in the spring (the only time it is offered) and then graduate in December, taking the capstone design course (offered every semester) during the fall semester. Faculty numbers and availability preclude offering ME Lab each semester. Another concern is that the students' major lab experience occurs in what is usually the last semester of their academic career. Recently, Baylor University has increased its emphasis on faculty research. With the current curriculum, students are not truly prepared to support the research initiatives until they graduate. This has prompted a series of discussions about shifting the lab experience to the sophomore year. Students would then be better prepared for future laboratory and research experiences. A one credit hour fluids/thermo lab would occur in the fall of the senior year leaving the spring semester of the senior year to take the capstone design course. Schedule changes are being considered and course development is underway with the possible implementation in three years. Another concern is the growing mechanical engineering enrollment. While growth is a good thing, individual grading of laboratory reports may need to be changed. This may lead group lab experiences.

Conclusion

This paper has highlighted the ME Lab course as it is currently taught at Baylor University with an emphasis on instruments used for assessment. It is a course which covers a variety of topics all designed to improve the laboratory skills of the students and to satisfy ABET Criterion 3 outcomes. As a laboratory course with a significant experiment component, students satisfy ABET Criterion b. Students are asked to use their communication skills to a high degree, satisfying ABET Criterion g. Students are exposed to various laboratory methods of measurement of basic fluid flow, temperature and pressure. A variety laboratory tools are used from basic manometers to sensitive micromanometers, hot-wires, and calibration quality pressure transducers, satisfying ABET Criterion k. The end result is that student laboratory skill levels increase. The faculty have confidence in the students' abilities as they graduate and pursue careers. Assessment tools were also discussed in the context of ABET assessment requirements. The course, in its present form, accomplishes its outcomes however; it is desired to expose the students to these skills earlier in the academic curriculum so that they can be reinforced in other courses and research laboratories.

Bibliography

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7. Baylor University Undergraduate Catalog, 2005-2006
8. EGR 4335, Mechanical Engineering Laboratory Course Policy Letter, Spring 2006
9. <http://journaltool.asme.org/Content/AuthorResources.cfm>
10. ASME Writing Guide for EGR 4335 – (Student handout developed for Baylor University, Mechanical Engineering Laboratory.)

APPENDIX A – Lab Report Memo Format and grading guide

DATE: (date lab is due)
TO: Dr Van Treuren
SUBJECT: (Lab title, followed by lab number)
FROM: (your name) sign your name adjacent

Introduction & Theory: (do not indent for paragraphs, use block format, # paragraphs sequentially)

1. This handout serves as the MEMO LETTER REPORT GUIDE for EGR 4335, Mechanical Engineering Laboratory. The letter report will be no more than two pages (single spaced, Times New Roman 10 font) in length (not including attachments) with one-inch margins and divided into the sections. For this section, give a short statement of the purpose and engineering application of the laboratory experiment (Your own words). What has been done and what is the point of the present experiment? No major theory development to be given here. Just give important relationships/equations and describe variables. Note assumptions.

Apparatus & Experimental Procedure: (continue paragraph numbering using the next number. Do not start with “1” for subsequent sections.)

2. Give a short description of the apparatus employed. No sketch required but a sketch should be included in the attachments. Give a short description of the experimental procedure. Note any potential problems areas.

Results: Several paragraphs may be needed.

3. State the results with sources for error. Refer to the appendix. Discuss results. Do results agree with theory and with expected or accepted values? Discuss significance of results and relate to engineering application. Grading will be greatly influenced by correct versus incorrect results. An attractive report with incorrect results will likely receive a fair grade! On the other hand, a hastily done report with correct results will not receive an excellent grade.

Attachments: (A list of the attachments will be included directly below the body of the letter and each will be labeled in the order referred to in the report)

- a. Laboratory Handout - (Instructor Furnished)
- b. Data Reduction Tables
Tables should have borders and titles. Show units under labels. Highlight important results.
- c. Graphs/Figures
The Graph should have sufficient information for the reader to understand without reference to report. Graphs must use standard conventions such as dependent variable on horizontal axis and independent variable on the vertical axis. Graphs must be numbered and given a descriptive title. Axis must be labeled and units indicated. Provide legend if needed. When possible use multiple plots on a single graph. Using a leader, reference the equation to the data on the plot.
- d. Sample Calculations
These should clearly show all typical calculations including data reduction, least squares data fitting, and error analysis. Reference sample hand calculations to the spread sheet (if used) by shading the appropriate cells. Show units clearly and how they cancel. Mathcad may be used instead of hand calculations if enough steps are included and the unit system is consistent.
- e. Data Sheet - Xerox copy of the original data sheet.
- f. Other Appendices as necessary.

Ten percent of the report will be based on presentation, neatness, grammar, etc.

**LETTER REPORT CHECKLIST
MECHANICAL ENGINEERING LAB**

STUDENT NAME _____

LAB NO _____

GRADED BY _____

GRADE _____

	<u>LOW</u>	<u>MED</u>	<u>HIGH</u>	<u>AVG</u>
I. <u>Introduction (10%)</u>	(1)	(2)	(3)	___
A. Explain the purpose(s) of the experiment	___	___	___	
B. Explain the engineering application	___	___	___	
C. Overview of the experiment	___	___	___	
II. <u>Theory (10%)</u>				___
A. Equations.	___	___	___	
B. Variables/symbols defined	___	___	___	
C. Assumptions/appropriateness	___	___	___	
III. <u>Apparatus (10%)</u>	___	___	___	___
IV. <u>Experimental Procedure (5%)</u>				___
A. Procedure	___	___	___	
B. Trouble points	___	___	___	
IV. <u>Results (25%)</u>				___
A. Results/Conclusions	___	___	___	
B. Comparison with theory	___	___	___	
C. Comparison with other accepted data	___	___	___	
D. Relevance to engineering	___	___	___	
V. <u>Attachments (30%)</u>				___
A. Tables of Results (Data).	___	___	___	
B. Graphs, labeled, units, legend, ect	___	___	___	
C. Sample Calculations	___	___	___	
B. Error analysis	___	___	___	
VI. <u>General (10%)</u>				___
A. Format and Neatness	___	___	___	
B. Grammar and Spelling	___	___	___	

Comments

APPENDIX B – Professor Evaluations of Student Presentations.

TEST PLAN and FINAL PROJECT PRESENTATION GRADING SHEET

PROJECT TITLE: _____ **Evaluator:**

Students:

UNDERSTANDING OF THE PROJECT _____/40

- Discussed previous work
- Understanding of instruments
- Able to answer questions

TECHNICAL ACCURACY AND COMPLETENESS _____/30

- Accurate theory presentation
- Uncertainty analysis

ORGANIZATION AND DEVELOPMENT _____/20

- Logical, well thought-out
- Not too short or too long (approx. 15 min.)
- Smooth transitions

PROFESSIONALISM/APPEARANCE _____/10

- Communicated clearly and effectively
- Used presentation materials effectively
- Polished

(ADDITIONAL COMMENTS: Use back side)

Suggested Grade: _____ (A 90 B 80 C 70 D 60 F Below 60)

APPENDIX C – Student Oral Presentation Critique Form

**EGR 4335 Mechanical Engineering Laboratory
ORAL PRESENTATION EVALUATION SHEET**

Name _____ Test Plan or Final Presentation (Circle one)

INSTRUCTIONS: Evaluate the other presentations in the following categories and place a score from **1 to 5** (1 being **well below average** and **5** being **well above average**) in each of the blocks. Total the scores for each individual and place this value in the Total column. If you have any written comments for a particular individual (things that were extremely well done or suggestions to improve their presentation) please write the comments below the blocks. Do not rate yourself!!!!!!

Individual	Understanding of Project	Technical Accuracy and Completeness	Organization/ Development	Professionalism/ Appearance	Total

Comments

Individual	Understanding of Project	Technical Accuracy and Completeness	Organization/ Development	Professionalism/ Appearance	Total

Comments

Individual	Understanding of Project	Technical Accuracy and Completeness	Organization/ Development	Professionalism/ Appearance	Total

Comments

Individual	Understanding of Project	Technical Accuracy and Completeness	Organization/ Development	Professionalism/ Appearance	Total

Comments

APPENDIX D – Project Report Evaluation Forms

EGR 4335 TEST PLAN GRADE SHEET

Name _____

	POINTS
OVER ALL APPEARANCE	/10
Neat, typed, project title and authors included	
References included	
OBJECTIVES	/10
What will be measured and why	
Well stated, concise	
BACKGROUND	/10
What's been done before	
Why the research is important	
Brief explanation of theory	
EXPECTED RESULTS	/5
What are the expected magnitudes of the measured parameters? Why?	
REQUIRED EQUIPMENT AND SUPPORT	/10
Detailed listing of model and serial numbers.	
What needs to be done before testing can take place.	
Software required.	
SETUP	/10
Detailed description of how the equipment should be set up.	
Includes sketch.	
CALIBRATION INFORMATION	/10
If necessary	
EXPERIMENTAL PROCEDURE	/15
Step-by-step plan for completing testing.	
Includes test matrix	
UNCERTAINTY ANALYSIS	/10
Includes the governing equation (if none - state so and describe the process by which fixed uncertainty is calculated).	
Includes all sources of error.	
States how instrument error was found (e.g. manufacturer's specs, calibration etc.)	
TIME LINE	/10
This should be detailed to include items such as lab prep, model fabrication, software development, initial testing, actual test runs, data reduction, report preparations, etc.	
TOTAL	/100

EGR 4335 Final Project Grade Sheet

NAMES _____

Abstract	/5
Title Page, TOC, List of Fig, etc	/5
Introduction	/15
Method	/10
Results	/20
Conclusions and Recommendations	/10
References	/5
Appendix	/15
Writing/Organization	/15

Comments: