Abstract

An innovative method was employed to create a number of experimental design projects through which students learn conceptualization of experiment, fundamental mechanisms, experimental process, data analysis, verification of physical laws, principles or phenomena. The Mechanical Engineering Program at Youngstown State University offers MECH 4835L, Thermal Fluid Applications Laboratory, in the Fall Semester. The laboratory is a companion course to a required senior-level course, MECH 4835, Thermal Fluid Applications. The laboratory deals with topics in the areas of fundamental and applied thermodynamics, fluid machinery and power, basic and applied heat transfer, and instrumentation and measurements. The laboratory is equipped with a number of commercial bench-top and wall-mounted experimental equipment which include temperature measurement, calorimetry, heat conduction, forced and free convection, condensation heat transfer, radiation heat transfer, refrigeration systems, internal combustion engines, flue gas analysis, pump operation, heat exchangers, and turbo machinery.

Although the experimental equipment has been well maintained, many devices have been in use for more than twenty five years. Consequently, some devices do not provide the results reliable enough for students to make positive observations on physical phenomena in order to draw a meaningful conclusion on the primary objectives. Moreover, some equipment was manufactured with inherent design flaws which might have been caused by over simplification of the design, poor construction, and inaccurate information on the design specifications provided by manufacturers.

Some of these troublesome experiments were identified and students were asked to select one of them for design modification with verified results obtained from the improved hardware and new experimental process. Students were also asked to present their new design and findings orally and by written reports to share the acquired knowledge to fellow students. The new method yielded very positive results related to students’ learning and strengthened the ability of students in designing experiments, analyzing the experimental data, verifying the hypothesis, and observing the entire experimental process for in-depth conclusion.
I. Introduction

Laboratory experiments are valuable tools with which students can efficiently learn abstract concepts. Many undergraduate engineering laboratory courses are designed to strengthen students’ understanding on fundamental physical laws and principles by providing the students with relatively simple experimental devices and hands-on experience with them. However, the reinforcement of the knowledge and understanding of the engineering principles only comes through clear understanding of experimental objectives and procedures, careful measurements for accurate data, thorough analysis, and proper interpretation of the results. Failure in meeting any one or more of the above aspects of experimentation will keep students from properly learning the subject and developing skills needed for advance experimentation.

The ABET 2000 assessment criteria [1] requires the outcome of students’ academic performances that includes students’ ability of designing and conducting their own experiments. For the past several years a variety of assessment surveys have been conducted in the Mechanical Engineering Program to investigate students’ opinion on the educational effects of laboratory courses through the exit interviews, alumni surveys, and student focus groups. The numerical data compiled from those surveys have showed that the ratings on certain categories such as designing components, systems, and experiments are lower than the other remaining outcomes [2]. Although the integration of design in the entire curriculum and strengthening the capstone design courses improved the ratings in recent years, students have not been fully confident in their design ability, especially designing and conducting their own experiments. These survey results are also consistent with the findings and observation of the author who has been continuously teaching Senior-level laboratory courses for the last twenty years. The author contends that there are two major reasons that prevent students from adequately developing the ability and skills. The first one is limited training due to insufficient exposure in handling open-end experiments, and the other is lack of opportunity in reviewing and improving imperfect experiments due to their own mistakes and/or inferior equipment by devising new experimental procedure and/or desired outcomes.

A typical undergraduate laboratory in basic natural sciences such as chemistry and physics offers students experiments with a rigidly defined experimental process that would demand only anticipated results. In this format of an experimental setup, students are required to strictly follow the experimental steps described in the lab handout and obtain predetermined outcome. For many years this closed type of practice also continued in the engineering laboratory due to a limited set of lab equipment and time constraints. Although the experiments could help students acquire a certain level of proficiency in conducting experiments and obtaining output data that verifies the principle examined in the experiment, they do not provide students with good opportunities in training themselves to deal with experiments that are not clearly formulated. Many students are accustomed to this spoon-fed instructional mode and are afraid of taking an active leadership role in formulating objectives, and conducting experiments for fear of not having expected results. It turns out that guiding students to successfully develop a meaningful experimental design project, even in the Senior-level laboratory course poses a challenge to instructors, especially in the area of thermal fluid sciences where a particular experimental setup often presents problems in dealing with allocated time, thermal equilibrium, instrumentation, and measurements.

II. Thermal Fluid Applications Laboratory

The students majoring in mechanical engineering at Youngstown State University are required to take four physical laboratory courses directly related to mechanical engineering. MECH 3720L, Fluid Dynamics Laboratory, and MECH 4835L, Thermal Fluid Applications Laboratory, are the two laboratory courses that cover the area of fluid thermal sciences while MECH 3751L, Stress Analysis Laboratory, and MECH 5892L, Vibration and Control Laboratory, cover the areas of solids, dynamics, control, and design. A new curriculum in the Mechanical Engineering Program set up the laboratory courses in this manner to provide students with a progressive learning opportunity through laboratorial work and development of advanced experimental skills. These lab courses also provide students with opportunities in improving critical thinking and written and oral communication.

1. The Goals of TFA Laboratory

The TFA Laboratory, being a Senior-level oral communication intensive laboratory course, is supposed to provide critical components in accomplishing the mission and the educational objectives of the Mechanical Engineering Program and to deliver multiple outcomes in students’ academic performances [3]. This laboratory course must be taken concurrently with the companion lecture course, MECH 4835, Thermal Fluid Applications. The lecture and laboratory courses are the last of the sequential courses in the area of fluid thermal sciences, which students must take to satisfy the graduation requirements [4]. Therefore, the courses must cover a variety of fundamental and applied subjects in thermodynamics, fluid power, and heat transfer. The experiments are almost equally divided into application oriented experiments and the ones that reinforce students’ understanding on fundamentals of thermodynamics and heat transfer. On successful completion of the course, students are expected to acquire an ability of: 1) analyzing a sample for thermodynamic properties by proximate and calorimetric analysis, 2) understanding the principles of temperature measurement, instrumentation, thermoelectricity, thermocouples, and thermopiles, 3) analyzing multi-bar 1-D conduction with a clear understanding of temperature gradient and contact resistance, 4) verifying the Stefan-Boltzman’s law and radiation exchange between surfaces, 5) analyzing the performance of double-pipe heat exchangers, internal combustion engines, gas turbines, and refrigeration systems, 6) utilizing computer software for analysis and design, 7) designing own experiments, 8) effectively presenting their work in written and oral communication.

The highlight of the course is the design project. By requiring the development of a team design project, the course also intends to help students develop skills for working within a team, effectively communicating in written and oral forms [5], in addition to conceptualizing experiment, formulating a hypothesis, designing experimental set-up and procedure, conducting experiment and data acquisition, analyzing the data, interpreting the results, and conclusion.
2. Laboratory Experiments

As seen in the attached syllabus, in a typical semester, nine experiments, two design sessions, and three oral communication activities are conducted on a weekly basis. The first four experiments deal with fundamentals of thermodynamics and heat transfer while the next five experiments are for application-oriented mode. The laboratory is equipped with a number of commercial bench-top, wall-mounted, and stand-alone experimental equipment. Although the experimental equipment has been well maintained, some devices have been in use for more than twenty-five years. Consequently, they do not provide the results reliable enough for students to make positive observations on physical phenomena in order to draw a meaningful conclusion on the primary objectives. Moreover, some equipment was manufactured with inherent design flaws that might have been caused by over-simplification of the design, poor construction, and inaccurate information on the design specifications provided by manufacturers. In other cases, due to prolonged time needed for desired equilibrium, students are often forced to obtain only one set of data for some experiments that may require, for better accuracy, multiple sets of data.

Some of these troublesome experiments include a 1-D heat conduction system, a radiation heat transfer, a double pipe heat exchanger, and a refrigeration system. The experiments utilizing this equipment usually generate inconsistent results that would interfere with accurate interpretation on certain physical phenomena. However, due to the tight schedule for weekly experiments, no remedial experimental sessions can be offered during the semester for experiments with erroneous results. Students usually rely on critical comments made by instructors on students’ laboratory reports to comprehend the effects and consequences of the errors. Thus, it has been considered for some time that the lab offers students an opportunity to make positive interpretation on the results obtained from redesigned experiments.

3. Design Projects

In one year, completely open-ended design projects were assigned with no restriction on subjects. Although a few teams were able to develop excellent projects on their own, some students made only a moderate success in formulating an experiment. In the following years, transient heat transfer problems associated with the lumped capacitance method and free or forced convection were selected for design projects. The handouts for sample design projects, as shown in the Exhibit 2, were distributed to students. Depending on these guidelines, students were able to generate a number of interesting experimental problems. Students proposed to build well conceptualized thermal fluid systems with adequate instrumentation to verify their hypothesis. However, due to the limit in budget and time spent for the projects, many projects were scaled down or the quality of some design products became marginal. Therefore, it was apparent that a new direction for the design was necessary to alleviate the problem. In Fall 2003, redesigning the problematic experiments was added to the existing design assignment as new design project. The guidelines for projects, as shown in the Exhibit 3, were handed out to the students. Students were asked to select one of the problem experiments for design modification with verified results that would be obtained from the improved hardware and new experimental process.
The underlying rationale in selecting these redesign projects can be listed as follows:

a) Students have a clear understanding of the objective, the procedure and the anticipated result of the experiment.
b) Students have a better chance of identifying the possible source of problems.
c) Students can devise the proper procedure for their experiment.
d) Students will have better data for logical interpretation of the results

In addition, students were also asked to present their new design and findings orally and by written reports to share the acquired knowledge to fellow students.

III. Summary of Projects

A design team consisted of three students. Four teams in one of the two sections of the course offered in the semester decided to choose the new assignment of redesigning. Each team selected one of the previously mentioned experiments, 1-D heat conduction, radiation heat transfer, double-pipe heat exchangers, and refrigeration system. Each team reviewed their previous experimental results, studied the experimental set-up, and found possible causes of the problems. Then, they proposed a new experiment, modified the system, conducted a new experiment, analyzed the data for much better results, and presented their findings to their peers orally and also in written reports to the instructor. A brief description of each project and summary of the findings are presented.

1. Heat Conduction

This experiment uses Scott Thermal Conduction Systems, Model 9051, to determine the thermal conductivity of copper, steel, aluminum, and magnesium using the Fourier’s law.

\[ q_x = -k A \left( \frac{dT}{dx} \right) \]

where the rate of heat transfer, \( q_x \), is evaluated by \( (\frac{dm}{dt}) c_p (T_0 - T_1) \).

Several possible sources of problems that plagued the original experiments are summarized in Table 1, along with improvements made for a new experiment and the compared results. The percent of error for the values obtained from the old and new experiments compared with the reference values [6] are also shown in the parenthesis in the table.

2. Thermal Radiation

This experiment uses Scott Radiation and Temperature Measurement Systems, Model 9053, to calibrate a thermopile pyrometer and verify the Stefan-Boltzmann law, \( E_b = \sigma T^4 \), by determining the power index, \( n \), in the equation, \( q = A \sigma T^n \), where \( n \) can be evaluated from \( n = \frac{(\ln q_1 - \ln q_2)}{(\ln T_1 - \ln T_2)} \). The accuracy of the pyrometer improved dramatically with the modified hardware and new instrumentation. The summary of the project is shown in Table 2.
3. Heat Exchanger

This experiment uses Scott Double-Pipe Heat Exchangers, Model 9052, to obtain the overall heat transfer coefficient, $U_i$, and the effectiveness, $\varepsilon$, for parallel and counter flow conditions. The uncertainty analysis was also conducted on the measured data. The summary of the project is shown in Table 3.

4. Refrigeration System

This experiment is conducted on a Hampden Refrigeration System to investigate the performance of the refrigeration system and the COP. Despite a good amount of time and effort put in this project, the results were not significantly improved, due to inherent design flaws. The summary of the project is shown in Table 4.

Table 1. Heat Conduction Project

<table>
<thead>
<tr>
<th>Source of Problems</th>
<th>Improvement made</th>
<th>$k$ (Btu/h<em>ft</em>R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Old (% error)</td>
</tr>
<tr>
<td>1. old instrumentation</td>
<td>1. use of NI data acquisition</td>
<td>copper = 359 (64.7)</td>
</tr>
<tr>
<td>2. inaccurate flow rate of coolant</td>
<td>2. install a new flow meter</td>
<td>steel = 48 (84.6)</td>
</tr>
<tr>
<td>3. back pressure control</td>
<td>3. one cooling system at a time</td>
<td>aluminum = 195 (63.9)</td>
</tr>
<tr>
<td>4. inaccurate coolant inlet temp.</td>
<td>4. change of thermocouple location</td>
<td>magnesium = 114 (23.9)</td>
</tr>
<tr>
<td>5. bad diversion valves</td>
<td>5. clean the valves</td>
<td></td>
</tr>
<tr>
<td>6. difficult to reach steady-state</td>
<td>6. transient heat analysis for estimation of the time</td>
<td></td>
</tr>
<tr>
<td>7. imperfect insulation</td>
<td>7. unchanged</td>
<td>constant</td>
</tr>
</tbody>
</table>

Table 2. Thermal Radiation Project

<table>
<thead>
<tr>
<th>Source of problems</th>
<th>Improvements made</th>
<th>Power index, $n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. inaccurate temperature of an</td>
<td>1. installation of device holding a thermocouple on</td>
<td>4.5</td>
</tr>
<tr>
<td>oven as a balckbody</td>
<td>oven opening</td>
<td>for original experiment</td>
</tr>
<tr>
<td>2. inaccurate thermopile</td>
<td>2. rearrange thermocouples in the thermopile</td>
<td>3.9</td>
</tr>
<tr>
<td>pyrometer</td>
<td>pyrometer</td>
<td>for new experiment</td>
</tr>
<tr>
<td>3. analog potentiometer</td>
<td>3. change to digital potentiometer</td>
<td></td>
</tr>
<tr>
<td>4. warped plate</td>
<td>4. new thicker plate</td>
<td></td>
</tr>
<tr>
<td>5. inaccurate plate temperature</td>
<td>5. attach more thermocouples for average temp.</td>
<td></td>
</tr>
</tbody>
</table>

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Copyright ©2004, American Society of Engineering Education"
Table 3. Heat Exchanger Project

<table>
<thead>
<tr>
<th>Source of problems</th>
<th>Improvements made</th>
<th>Results</th>
</tr>
</thead>
</table>
| 1. bad thermocouple locations for junction  
2. a single flow meter for both flows  
3. inaccurate temperature readings   | 1. installation of thermocouples at new locations   
2. unchanged                          
3. use of new data acquisition system and clean thermocouples | Improve the effectiveness and $U_i$ of counter and parallel flow exchangers by 20 % and 5 %, respectively. |

Table 4. Vapor Compression Refrigeration Project

<table>
<thead>
<tr>
<th>Source of problems</th>
<th>Improvements made</th>
<th>Results</th>
</tr>
</thead>
</table>
| 1. over designed evaporator             | 1. restrict the air flow through the evaporator coil   
2. inaccurate junction temperatures   
3. inaccurate coolant flow rate  
4. negative entropy gain during compression  
5. large heat loss from connecting tubes | Improve the COP only slightly.  
Could not overcome problems associated with the evaporator and compressor.  
4. unchanged                          
5. unchanged                          |-------------------------------------------------------------------------|

IV. Conclusion

The new design assignment produced worthwhile experimental projects. The experiments, except the refrigeration system, generated dramatically improved results that were well compared with theoretical values or published data [7]. By redesigning the experiment that the students are already familiar with, they were far more confident with what they were doing and why they are doing it. The students reviewed the original experiments, identified the possible cause of problems, and hypothesized their reasoning. During the process, the students learned and found how they conduct experiments for success. Some of the improvements made for the projects were permanent changes to the equipment and process, while others are temporary measures. The project strengthened the ability of students in designing experiments, analyzing the experimental data, verifying the hypothesis, and observing the entire experimental process for in-depth conclusion. They were extremely satisfied with their new design project that would be used and further improved by the next group of students. The students felt that they learned much more about experimentation than the students who chose the other type of open-end design projects.
Bibliography

1) ABET, Criteria for Engineering Programs 2003 - 2004, November 2003
2) Kim, H. W., Annual Report for 2002-03, The Department of Mechanical and Industrial Engineering, Youngstown State University, June 6, 2003
4) Youngstown State University, Undergraduate Bulletin 2003-2005
6) Scott Engineering Sciences, Thermal Conduction System, Pub. No. 9051, Pompano Beach, FL

H. W. Shawn Kim
H. W. Shawn Kim is a Professor of Mechanical Engineering and Chair of the Department of Mechanical and Industrial Engineering at Youngstown State University. He has been teaching and developing the Thermal Fluid Applications course and the companion laboratory course for the past few years. He is a registered Professional Engineer in Ohio and is currently conducting applied research in fluid power. He helps the local industry with his expertise in heat transfer and thermal sciences. Dr. Kim received a B.S.E. degree from Seoul National University, a M.S.E. from the University of Michigan, and a Ph.D. from the University of Toledo.

Exhibit 1. Course Syllabus
Exhibit 2. Traditional Laboratory Design Guidelines
Exhibit 3. Innovative Laboratory Design Guidelines
Exhibit 1. Course Syllabus

Youngstown State University
Department of Mechanical & Industrial Engineering

MECH 4835L Thermal Fluid Applications Laboratory -- 1 Semester Hour Fall 2003

Prerequisites: MECH 3720, MECH 3725, taken concurrently with MECH 4835
Classroom: Moser 1230 Class Meets: M 1400 - 1650 (for 5417) or Th 1400 -1650 (for 5418)
Instructor: H. W. Kim, Ph.D., P.E. Home Phone: 
Office: Moser 2515 E-mail: hwkim@ysu.edu Office Phone: 941-3015
Office Hours: M T W Th F 11:00 - 12:00
Text: None
Probability & Statistics Outline, Dept of Mechanical Engineering, YSU, 1995
Supplemental Materials: one 3.5” - 1.44 Mb diskette, Calculator, A three-ring Binder
Lab Supplies: As needed for experiments

Objectives of Course:

To provide mechanical engineering students with a hands-on experience in conducting and/or designing experiments on thermodynamic properties, heat transfer, heat exchangers, power and refrigeration cycles, head loss in piping systems, prime movers, combustion and energy conversion processes, and other selected thermal-fluid devices. This course also serves as an oral communication-intensive course of the General Education Requirements. On successful completion of this course, students are expected to
I. apply the principles of thermodynamics to analyze sample coals for thermodynamic properties and heating values by proximate and calorimetric analyses
II. utilize a variety of temperature measuring devices and instruments to obtain temperatures, and be able to interpret their accuracy
III. understand the principles of thermoelectricity, thermocouples, and thermopiles
IV. analyze multi-bar 1-D heat conduction by thermal resistance method
V. understand clearly the concepts of temperature gradient and contact resistance
VI. verify the Stephan-Boltzmann’s law and net radiation exchange between surfaces
VII. analyze the performance of double pipe heat exchangers
VIII. analyze the performance of internal combustion engines
IX. analyze the performance of gas turbines
X. analyze the performance of refrigeration systems
XI. be capable of applying the principles of thermodynamics, fluid dynamics, and heat transfer
XII. to design and analyze their own experiments
XIII. utilize computer software for analysis and design of thermal fluid systems or components
XIV. effectively present their work in written and oral form of communications.
Topics Covered:

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic (3 contact hours/week)</th>
<th>Report Type/Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lab orientation</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Exp. 1: Proximate analysis and calorimetry</td>
<td>Written individual / Sep</td>
</tr>
<tr>
<td>11/15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Exp. 2: Temperature measurement</td>
<td>Written group / Sep 18/22</td>
</tr>
<tr>
<td>4</td>
<td>Oral and written communication review</td>
<td>Oral discussion / Sept. 18/22</td>
</tr>
<tr>
<td>5</td>
<td>Exp. 3: Conduction heat transfer</td>
<td>Written individual / Oct. 2/6</td>
</tr>
<tr>
<td>6</td>
<td>Exp. 4: Radiation heat transfer</td>
<td>Written group/ Oct. 9/13</td>
</tr>
<tr>
<td>7</td>
<td>Proposal for design project</td>
<td>Oral pres., review / Oct 9/13</td>
</tr>
<tr>
<td>8</td>
<td>Exp. 5: Heat exchangers</td>
<td>Written individual/ Oct.23/</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Exp. 6: Refrigeration system</td>
<td>Written group/ Oct.30/ Nov.3</td>
</tr>
<tr>
<td>10</td>
<td>Exp. 7: Gas turbine</td>
<td>Written group / Nov. 6/10</td>
</tr>
<tr>
<td>11</td>
<td>Exp. 8: Design project</td>
<td>Written group / Nov. 20/24</td>
</tr>
<tr>
<td>12</td>
<td>Exp. 9: Internal combustion engine</td>
<td>Oral discussion / Nov 13/17</td>
</tr>
<tr>
<td>13</td>
<td>Exp.10: Pump operations</td>
<td>Oral impr report / Nov. 20/24</td>
</tr>
<tr>
<td>14.</td>
<td>No Lab (Thanksgiving)</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Oral presentation for Design Project</td>
<td>Oral presentation &amp; review /</td>
</tr>
<tr>
<td></td>
<td>Course Review</td>
<td>Dec 1/4</td>
</tr>
</tbody>
</table>

Course Contribution to meeting the Professional Components:

This senior-level laboratory course is part of the required minimum of 1.5 years of engineering topics, and contributes 1 semester hour of engineering sciences and engineering design to mechanical engineering. This course emphasizes utilization of simple devices to confirm and verify a variety of thermal fluid principles and physical laws. The hands-on experience will facilitate students’ understanding on abstract concepts and strengthen the capability of these students in applying the principles to problem solving or to real engineering processes in analyzing and designing a variety of thermal-fluid devices, machinery, and systems. It is a companion laboratory course complementing MECH 4835, Thermal Fluid Applications. It requires prior knowledge in thermodynamics, fluid mechanics, and heat transfer.

Course Relationship to Program Objectives:

This course is one of the two oral communication intensive courses that the Mechanical Engineering designates to satisfy the University General Education Requirement. Students are expected to develop and improve their oral communication through a variety of activities that include review of speech making, impromptu speech, oral report, group discussion, and formal
oral presentation. In addition, it is anticipated that each student completing this course will have
developed the knowledge, skills, and capability necessary to partially satisfy 5 of the 7 program
outcomes defined in the program educational objectives. They are outcomes 1, 2, 3, 4, and 6.
The goals of this course are to strengthen the capability of students in formulating experimental
models, finding proper procedure of gathering experimental data, analyzing and disseminating
the data by utilizing analytical skills and modern computing tools, interpreting the results, and
designing an experiment for thermal fluid systems or components from conceptualization to
conclusion. Added benefits acquired in the process are improved critical thinking ability,
developing written and oral communication skills, and working with other individuals for team
projects, so that each student attains these essential professional skills to a level acceptable for
normal engineering practices.

Evaluation

Written Reports
Group (C.T., Res., Comm., Teamwork) 5 x 6% = 30%
Individual (CT, Res., Comm.) 3 x 10% = 30%
Oral Activities
Pres. & Review (C.T., Res., Design, Comm.) 2 x 10% = 20%
Impromptu Report (Comm., C.T.) 1 x 10% = 10%
Group Discussion (Comm., C. T., T. W.) 2 x 5% = 10%

Grade Scale
A -- 89 – 100 B -- 80 – 89 C -- 70 – 79 D -- 60 - 69 F – 0 - 60

I. Course Policies

Attendance: Required.
Class Participation: Absolutely necessary.
Missed Exams/Assignments: No make-up experiment will be arranged.
No late reports will be accepted.
Lab Safety: Use eye and ear protection when needed. You must take every precaution for
your safety and that of your fellow students.
Academic Honesty: Zero points will be given on the exams or assignments if students
participate in acts of academic dishonesty. See p.36 of the Undergraduate Bulletin.
Grade of Incomplete: No “I” grade will be given unless an official condition is met.
Support Services: Computing in Moser Hall 2380. See the College Computing Coordinator
or student monitor for further information.
Disability Services: In Accordance with University procedures, if you have a documented
disability and require accommodations to obtain equal access in this course, please contact the
instructor privately to discuss your specific needs. You must be registered with the Disability
Services Office in Beeghly Hall, Room 3310 and provide a letter of accommodations to verify
your eligibility. You can reach the Disability Services Office at (330) 941-1372.
About Lab Preparation

Laboratory problems are generally open ended by nature. There are discoveries and observations to make. You are expected to apply concepts learned from a variety of engineering courses to the experiment being conducted. The knowledge confirmed from the laboratory must be integrated with information from other classes to gain maximum benefit from the activities. Preparation for experiments is of essential importance for a successful laboratory since time is limited. You should read the laboratory handouts and introductory reference material, if required, carefully and come prepared with a “game-plan” to complete the assigned work. This might include a procedural outline and sample data sheets ready to fill out. In addition, this laboratory will provide you with an opportunity to engage in designing and conducting your own experiment. Use your knowledge and engineering judgment with some imagination in cooperative group efforts to create a new experiment for a special project.

About Written Laboratory Report

An experiment is supposed to be duplicable if the same procedure is followed, although not all experiments yield the exact same results. Therefore, good documentation is absolutely necessary. For formal reports, document everything that you do and everything you learn. The grading of these formal reports will be based on a systematic presentation of the problem definition, procedure, pertinent data, analysis of data, final results, and your comments or group discussions and observations. The analysis may include diagrams, assumptions, and the applications of fundamental principles. Follow the “Laboratory Report Writing” guidelines. The formal report must be typed on a word processor. Microsoft Word is preferred along with Excel. Computers and the software are available in the Engineering Computer Rooms. Informal reports emphasize the results and require a less stringent format and neatness. They can be hand-written in pencil. Written reports are due one week from the date that the experiment was performed. All reports must contain the data sheet(s) with the instructor’s initials to receive credit. Since the experiment requires a group effort and the raw data should be identical for every report filed by group, it is time consuming and repetitious for every person in the group to write a complete individual report each time. Therefore, group reports are required for a majority of experiments except three experiments.

About Oral Communication Activities

Oral communication is one of the very important areas where students must make significant achievements through this course. There will be a review session for oral communication, two presentations for your special projects and reviews on the presentations, two group discussions, and an oral impromptu report related to experimental activities. Each group must make two major presentations (30 – 40 minutes per each presentation) with all members of the group sharing approximately an equal amount of presentation time.
Exhibit 2. Traditional Laboratory Design Guidelines

YOUNGSTOWN STATE UNIVERSITY
DEPARTMENT OF MECHANICAL & INDUSTRIAL ENGINEERING

MECH 4835L THERMAL FLUID APPLICATIONS LABORATORY

INSTRUCTION AND GUIDELINES FOR A SAMPLE DESIGN PROJECT
“DESIGN PROJECT FOR CONVECTION HEAT TRANSFER”

Object: To design an experiment investigating convection heat transfer from a three dimensional solid, to build experimental devices and procedure, to verify appropriateness of the experimental setup and the theory, and to demonstrate the accuracy of results.

Apparatus: K and T type thermocouples, digital thermometers, National Instrument data acquisition system, blower, stopwatch, heater or heating oven, anemometer, specimen, and other equipment depending on your design

Theory: Determining the heat transfer coefficient on the surface of a three-dimensional solid is not a trivial matter due to difficulty of obtaining accurate surface temperature and the rate of heat transfer from the object. One simple method that can be used to determine this coefficient is the lumped capacitance approximation when the solid is subjected to convection. The method assumes that temperature of the lumped mass is nearly uniform over the entire solid at any instant and the temperature changes depending upon time only. In other words, there are negligible temperature gradients within the solid, which means negligible resistance to conduction compared to the resistance to convection. When a warm body is cooled by a cold fluid stream, the rate of heat loss from the body is proportional to the difference in temperature between the surface of the body and the ambient fluid. The principle of energy balance indicates that the rate of heat loss from the surface of the solid is identical to the rate of change of the internal energy within the solid. Since there is no conduction within the solid using the lumped capacitance method, the rate of change of the internal energy within the solid can be expressed in simple terms. Solution of this energy balance equation yields the heat transfer coefficient and the overall heat loss. The lumped capacitance method works well if the Biot number is smaller than 0.1.

Procedure: Study the theory of transient heat transfer and find necessary equations for your experimental setup. Check if your conceptual setup for the experiment is realistic and simple enough to be built. Design and build the devices. The system with automatic computerized data acquisition will earn more points. Establish an experimental procedure to obtain the necessary data. Conduct the experiment and analyze the data for the final results and compare them with the literature. Review the entire process to check if the objectives of the experiment were satisfied. What are the effects of radiation heat transfer on this experiment?

Report: A proposal describing concept of the design, objectives, experimental setup, and anticipated results must be orally presented by all members of your group on Thursday, October 9 and Monday, October 13. Final group report must document the entire design project. Submit a formal written report that includes clearly written objective, experimental data, analysis of data, results, and conclusions for the project on Monday, November 24. A laboratory hand out assigning the designed experiment must be developed and attached to the report. Oral presentation for the project is also required and will be held in Room 2400 on December 1 and 4.

Exhibit 3. Innovative Laboratory Design Guidelines

YOUNGSTOWN STATE UNIVERSITY
COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL & INDUSTRIAL ENGINEERING

MECH 4835L THERMAL FLUID APPLICATIONS LABORATORY

INSTRUCTION AND GUIDELINES
FOR NEW LABORATORY DESIGN PROJECTS

Object: This year’s design project is an unconventional, but potentially excellent one. It is anticipated that it will strengthen, not only your understanding on the theories and fundamentals of physical phenomena associated with the conducted experiments, but also on the fundamentals of experimental investigation and painstakingly repeated processes that usually accompany most experiments related to thermal fluid science and engineering. By conducting this laboratory project, you will learn and/or acquire the following skills:

1. detailed physical meaning of physical laws and equations that the experiment intends to verify
2. how the particular experiment is set up
3. how the desired data is gathered for accurate results to minimize random errors
4. how to find the system errors based on preliminary analysis
5. make a hypothesis for the design improvement that may include the methods of data acquisition, process changes, and/or hardware modifications.
6. modify the experiment and hardware
7. develop and conduct the new experimental process
8. analyze the data and verify the accuracy

Assignment:

1. Select one of the following experiments that were already conducted in this laboratory:
2. Thoroughly reinvestigate the selected experiment.
3. Find the random and system errors to minimize them and devise a plan to improve the existing hardware, instrumentation, and process.
4. Incorporate the new design and develop new experimental process.
5. Make an oral presentation regarding your new design
6. Conduct experiments to analyze the data and verify the accuracy
7. Submit a complete written report that includes all pertinent information about the development of the experiment, lab handout, a sample experiment, and analysis that verifies your design
8. Make an oral presentation on the design project.

Report: A proposal describing the concept of the design, tentative experimental setup, and anticipated results must be orally presented by every member of your group on November 13. A final group report must document the entire design project. Submit a formal written report that includes a laboratory handout, experimental data, analysis of data, results, and conclusions for the project on November 26. The final oral presentation by each member will be held in Room 2400 on December 4.