58:080
EXPERIMENTAL ENGINEERING

LAB GUIDELINES

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
THE UNIVERSITY OF IOWA
IOWA CITY, IOWA

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SPRING 2014

58:080 Experimental Engineering
COURSE ORGANIZATION
Spring 2014

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Purpose of Course
The purpose of this class is to gain proficiency in designing, assembling, and operating an experiment and then analyzing and presenting the results. This encompasses skills such as understanding control and data acquisition electronics, operation and limitation of sensors, calibration and error analysis, assessing applicability of theory and the impact of secondary experimental variables, and writing and presenting reports and analysis.
Writing reports is a significant component of this course. In the real world, promotion and corporate visibility depend on the impression that reports convey. A well written report is a strong advocate for your abilities.

Method
The best way to learn experimentation is by doing. This translates into a focus on performing more (and a wider variety) of experiments. Earlier reports will be shorter than later ones. As topics such as error analysis are covered in detail, later reports are expected to reflect this knowledge. Overview of Course Requirements:

1 individual technical memo (2 pages)
1 individual lab report (10 pages)
1 independent final group project report and presentation (10 pages)
6 experimental log book entries (3 individual, 3 group log book entries)
*****ALL labs must be completed satisfactorily for a passing grade*****

Due Dates: All lab reports and technical memos will be due as described in the schedule. Students must complete and submit all major assignments to pass the course.

Textbook
Figliola, Richard S. and Beasley, Donald E., *Theory and Design for Mechanical Measurements*, 5th Edition, John Wiley and Sons, Inc, New York, 2011. (Required).

Laboratory Guidelines and Lecture Notes
Lab Handouts will be available online.

Log Book
Bound, cross-lined (quad ruled) laboratory notebooks such as ***Roaring Spring 77591, Mead***

09926 (quadrille), Laboratory Notebook CompanyWR-150-100,
DO NOT buy Log Books with carbon paper. Get log book by second lab meeting on Thursday.

References

All other instrumentation manuals, handouts, lab manual, reports, etc are available online. The class website is http://www.engineering.uiowa.edu/~expeng/.

Course Description

Principles of physical measurements; standards calibration, estimation of error; uncertainty analysis; static and dynamic performance of measuring systems; laboratory experience, experiment planning, report writing. Prerequisite: 57:018. Co-requisites: 58:045 and 58:052.

Course Requirements

1. Active participation during scheduled laboratory periods and lectures, including a willingness to be available outside of class for further work and discussions. There should be no conflicts or excuses that prevent meeting with the group at scheduled lab periods.
2. Reading -- lecture notes, instructional manuals, handouts, textbook, references.
3. Grading -- to receive a non-incomplete grade, students must actively participate in the laboratory and lecture sessions, complete all of the logbook and report assignments in a timely manner, and complete the exams.

Assignment	Points per Assignment	Number of Assignments	Course Points Possible	Course Percentage
Lab Safety Procedures			*40*	2 %
Individual Log Books	100	3	*300*	15 %
Group Log Books and lab participation	60	3	*180*	9 %
Individual Technical Memo	100	1	*100*	5 %
Individual Technical Report	500	1	*500*	25 %
Final Project - Group Report	300	1	*300*	15 %
Final Project - Group Presentation	200	1	*200*	10 %
Homework	20	9	*180*	9 %
Exams	100	2	*200*	10 %
		Total Course Points Possible --------->	*2000*	100 %

Note that 57% of your course points are determined by your individual work, and 43% by group work. Also, 84% of the grade is determined by Lab work and reporting, and 16% by exams and homework.

Objectives

The overall objectives of the **Experimental Engineering** course are to develop (1) an awareness and understanding of experimental methods with particular applications to mechanical engineering and (2) ways to communicate effectively the experimental methodology, results, and conclusions. These objectives are accomplished by the following methods:

a) familiarization and utilization of instrumentation in terms of accuracy, precision, repeatability, response, range of application, construction, calibration, and application;

b) development of experimental objectives, design, and procedures required to perform satisfactorily the experiment;

c) acquisition, reduction, and analysis of experimental results;

d) written and oral reports for effective communication of experimental procedure, results, and recommendations to others.

ABET Criteria and Assessment Instruments related to Experimental Engineering

Criteria	Degrees of Achievement			
	Unsatisfactory 0 (0-50)	**Marginal 1 (50-70)**	**Satisfactory 2 (70-85)**	**Exemplary 3 (85-100)**
Lab Safety	No appreciation of safety guidelines	Unsafe lab procedures frequent.	Unsafe lab procedures infrequent.	Observes good lab safety procedures.
Instrumentation usage	Does not understand how the instruments work. Cannot select appropriate instrumentation to perform measurements. Is unable to operate the instrumentation provided.	Has minimal understanding on how instruments operate. Needs significant supervision to select the proper equipment and instruments, and to operate equipment.	Has mostly a basic understanding on how instruments operate. Needs some guidance to select the proper equipment and instruments, and to operate equipment.	Has an understanding on how instruments operate. Can select the proper equipment and instruments, and is able to properly operate equipment.
Experimental procedures	Cannot follow experimental procedures. Unable to formulate a logic experimental plan. Data documentation is poor leading to loss of data.	Has problems following the logic of the procedures in pre-set experiments. Requires significant supervision to develop and implement experimental procedures. Is aware of standards on data collection and documentation, but has problems following them.	Mostly understands the logic of the procedures in pre-set experiments. With guidance, is able to develop and implement experimental procedures. Follows standards on data collection and documentation, though occasional oversight can cause loss of efficiency or data.	Understands the logic of the procedures in pre-set experiments. Improves on what is suggested. Is able to develop and implement sound experimental procedures. Follows good standards on data collection and documentation.
Error analysis	Is unaware of the importance of error analysis. Cannot compute errors.	Is aware of measurement errors but has problem applying the theory, and requires significant help to achieve a final result.	Is aware of measurement errors and can estimate most, but requires some help to achieve a final result.	Defines and estimates elemental errors. Produces proper statistical estimates of precision errors and evaluation of bias errors, and propagates to final result.
Data analysis	Cannot relate data to theory.	Attempts analysis of the data, but does so with considerable errors.	Most of the time analyzes the data correctly, but does not have grasp of the theory behind. Misses results that are not included in the write-ups.	Uses appropriate theory to analyze the data, and extracts information from it. Identifies features in the results that are of interest or deviate from the theory or expected outcome.
Experiment design	Unable to design an experiment.	Needs considerable guidance and supervision to design an experiment. Has problems obtaining good data and meaningful results.	Can mostly design adequate experiments. Chooses instrumentation, designs procedures, acquires data, performs analysis and obtains meaningful results with some help.	Able to design an experiment that will produce the desired outcome. Can choose instrumentation, design procedures, acquire the data, perform analysis and obtain meaningful results without help.

	Assessment Instrument
Lab Safety	Laboratory observation throughout the semester (graded daily by TAs) and quiz.
Instrumentation Usage	Individual Logbooks in Labs 1/2. Problems in midterm Exam II.
Experimental procedures	"Experimental considerations" section in individual technical report (ITR).
Error analysis	All questions in midterm Exam I, "Error Analysis" section in ITR.
Data analysis	"Results and discussion" section in ITR.
Experiment design	Individual log book in Final Project.

Criteria	Degrees of Achievement			
	Unsatisfactory 0 (0-50)	**Marginal 1 (50-70)**	**Satisfactory 2 (70-85)**	**Exemplary 3 (85-100)**
Organization in writing	No sequence of information. No graphics. Poor discussion and conclusions. Poorly designed contents.	Poor sequence of information. Some graphics but not referenced. Limited discussion and conclusions. Unclear content.	The student has used logical sequence of information. Some graphics are used to explain and interpret the text. Proper discussion and conclusions. Clear content.	The student has used logical sequence of information. Proper graphics are used to explain and interpret the text. Thoughtful discussion and conclusions. Clear and interesting writing.
Writing skills	Numerous grammar and spelling errors. Long and confusing sentences. Poor syntax.	A few grammar and/or spelling errors. Understandable sentences. Fair syntax.	Hardly any grammar and/or spelling errors. Good syntax and sentences.	Error free. Appropriate and concise syntax and sentences.

	Assessment Instrument
Organization in writing	Individual technical report in 58:080. The assessment of this criterion is based on 1) the employment of logical sequence of the information; 2) usage and interpretation of graphics; 3) discussion and conclusions; and 4) clarity of the content.
Writing skills	Individual technical report in 58:080. The assessment of this criterion is based on 1) grammar spelling errors; 2) sentence structures; and 3) syntax.

Criteria	Degrees of Achievement			
	Unsatisfactory 0 (0-50)	**Marginal 1 (50-70)**	**Satisfactory 2 (70-85)**	**Exemplary 3 (85-100)**
Use of hardware and laboratory equipment	Very limited knowledge about laboratory equipment; no attempts made to learn.	Has general idea of hardware and equipment, but the selection is ineffective; uses them but needs significant assistance.	Knowledgeable about lab equipment and hardware; selects appropriate pieces; knows their use for lab tests, design or research.	Same as (2); knows hardware limitations and their efficient use; uses them very effectively.

	Assessment Instrument
Use of hardware and laboratory equipment	Individual Log Books in Labs 1/2 and Individual Log Book in Final Project (58:080 Experimental Engineering). These experimental projects require the students to use instrumentation to complete a fairly complex experiment (Lab 1/2), and to design and run an experiment (Independent Project).

Experimental Engineering Lab Policies

1. Lab Attendance Policy

Attendance to the lab is mandatory to receive a passing grade. 50% of the total possible log book score will be subtracted for every ½ hour of lab class you miss without an excused absence. Contact the course instructor to receive an excused absence **before** an unavoidable conflict with lab occurs. Excused absences will need to be made up at a later date. An absence is excused only for a medical condition supported by a doctor's report.

2. Lab Log Book "Home Work"

- If there are "Pre-lab questions" for a lab, you must answer them in the log books prior to the start of each lab. The answers will be written in ink in each logbook, and will be checked and signed-off by the TAs during the first lab session meeting on a given experiment. The Pre-lab questions are graded when the log book is graded.
- In order to make your lab work less hectic, and improve the log book readability, you may begin to write and layout the Procedures portion of your log books before you come to lab. This requires you to read the lab description before you come to lab, which you must do anyway! You must always start the new lab session on a new page in the log books, so please observe this practice when you start a log book entry outside of the lab session. Write the date for the lab session day you will be performing the lab work.
- Similarly, you can complete the "Discussion" and "Conclusions" sections after the lab (remembering to always start you next lab session on a new page). Data reduction, the example calculations included in the log book, can also be time consuming and can be done outside of class.
- Note also that there may be times when you may have to interrupt a log entry for one lab with the start of another. Say, for example, you did not quite complete one lab before you had to start another. In this case, write "(continued on page xx)" at the bottom of the last page of the uncompleted lab entry, begin the new lab as always, and then put the remainder of the uncompleted lab after the new lab, taking note of the starting page for the "continued" portion in order to fill in the blank for the "(continued on page xx)" note.

3. Late Policy for Lab Reports

Lab reports and log books will have 10% of the total possible score deducted for every day they are turned in late. Reports will be due by 5:00 p.m. on the dates they are due. Reports must be turned in below the door to 2256 SC or to your lab TA.

4. Homework

Completing all the homework is the responsibility of the student. Homework problems will be graded randomly, with about 50% of the problems chosen for grading for every homework due. Students are encouraged to work on all the assigned homework problems.

5. Lab safety guidelines

The lab has potential hazardous instruments and tools. Please follow these guidelines:

General:

1) No food (sandwiches, candy, fruit, etc.) or drinks (soda, coffee, etc.) are allowed in the laboratory. A spilled cup or wayward crumbs could be very harmful to the instruments and create a safety hazard.
2) Maintain clean and orderly laboratories and work areas. Discard immediately unwanted paper, wires, nuts, and other items. Place coats and books on shelves or hooks. Make sure all spilled liquids (water, oils, etc.) are wiped up immediately.
3) Be careful of protruding objects and wires or tubing on floors. These are kept to a minimum, but there may be instances when they occur.
4) Any injuries should be reported immediately for proper care.
5) Keep aisles clear and walk in aisles to the extent possible.
6) You are responsible for maintaining your work area in a safe and reasonable condition.
7) Do not leave experiments running unattended unless explicit permission has been granted by the TAs.
8) At least two members of the team must be present while performing experiments or operating instrumentation or machinery.

Electrical (https://research.uiowa.edu/ehs/files/documents/occsafety/fireandelectricalsafety.pdf):

1) Be careful of all electrical instruments. Watch for worn power cords.
2) Always ground instruments and equipment. Attempt to always connect the ground lead first, not the signal lead first and then the ground lead.
3) Unplug electrical equipment before repairing or servicing it.

Mechanical:

1) Never wear gloves when working with equipment that has exposed moving or rotating parts.
2) Always maintain awareness of activity around you.
3) You must be aware of the various machine controls (start button, stop button, speed-change control) for each machine you are authorized to operate.
4) Wear ANSI-approved safety eyewear with side shields whenever operating a material-grinding machine.
5) Restrain (i.e., cover or tie back) long hair that could get caught in moving parts.
6) Wear ear protection when operating the air turbine and other noisy experiment.

58:080 Experimental Engineering, Spring 2014: Schedules

Lectures	12:30-1:20	Tu, Th	2229 SC	P. M. Carrica	10 students
Lab 001	8:30-10:20	Tu, Th	2256 SC	Seth Dillard, TA: Yuwei Li	8 students
Lab 002	10:30-12:20	Tu, Th	2256 SC	Seth Dillard, TA: Yuwei Li	17 students
Lab 003	1:30-3:20	Tu, Th	2256 SC	Seth Dillard, TA: Alireza Mofidi	22 students
Lab 004	4:30-6:20	Tu, Th	2256 SC	Seth Dillard, TA: Alireza Mofidi	21 students

Period	Date	Lecture Topics	Text Reading	Lab Activity	What's due
1	1/21	Intro, Ch.1 Basic Concepts	pp. 1-31	Grouping, Logbooks	
2	1/23	Ch. 2 Signals, Ch. 6 Analog Devices		Mini-lab 1	
3	1/28	Labview, Data Acquisition	Intro to data acquis. with Labview.	Mini-lab 2	
4	1/30	Ch. 4 Statistics. Exam Lab Safety.	pp. 118-128	1st Choice of Lab 1/2	GLB1
5	2/4	Ch. 4 Statistics	pp. 129-152	Cont 1st Lab 1/2	HW1
6	2/6	Ch. 5 Uncertainty	pp. 161-167	Cont 1st Lab 1/2	GLB2, ITM
7	2/11	Ch. 5 Uncertainty	pp. 168-182	Cont 1st Lab 1/2	HW2
8	2/13	Uncertainty Examples		Cont 1st Lab 1/2	
9	2/18	Uncertainty Examples		2nd choice of Lab 1/2	HW3
10	2/20	Lab Experiments		Cont 2nd Lab 1/2	ILB1 (on 1st Lab 1/2)
11	2/25	Review		Cont 2nd Lab 1/2	HW4
12	2/27	Exam I		Cont 2nd Lab 1/2	
13	3/4	Ch. 3 Measurement System Response	pp. 79-92	Cont 2nd Lab 1/2	HW5
14	3/6	Ch. 3 Measurement System Response	pp. 92-95	Cont 2nd Lab 1/2	
15	3/11	Ch. 3 Measurement System Response	pp. 95-104	3rd choice of Lab 1/2	
16	3/13	Ch. 3 Measurement System Response	pp. 104-11, 509-516	Cont 3rd Lab 1/2	ILB2 (on 2nd Lab 1/2)
Spring Break					
17	3/25	Final project discussion	pp. 504-509, 516-533,	Cont 3rd Lab 1/2	HW6
18	3/27	Ch.12 Displacement, Load, Torque Meas.,	375-396	Cont 3rd Lab 1/2	

		Ch. 9 Pressure, Velocity Measurements			
19	4/1	Ch. 9 Velocity Measurements	pp. 396-415	Cont 3rd Lab 1/2	HW7
20	4/3	Ch. 10 Flow Measurements	pp. 423-461	Cont 3rd Lab 1/2	
21	4/8	Review and examples		Final Project	HW8
22	4/10	Review and examples		Final Project	GLB3, ITR (on 3rd Lab 1/2)
23	4/15	Exam II		Final Project	HW9
24	4/17	Final Project		Final Project	
25	4/22	Final Project		Final Project	
26	4/24	Final Project		Final Project	
27	4/29	Final Project		Final Project	
28	5/1	Final Project		Final Project	
29	5/6	Final Project		Final Project	
30	5/8	Final Project		Final Project	ILB3 (on Final Project)

Final Exam Week; Final Project presentations date TBA. Final Project reports due May 11th at 5:00 pm in the lab.

Notes:

§ Log book entries will be kept for every experiment, during every lab session; in particular, Group Log Book (**GLB**) entries will be completed for all minilabs and the third Lab 1/2, corresponding to the Individual Technical Report (**ITR**). Individual Log Book (**ILB**) entries will be completed for the first two Labs 1/2 and the Final Project (**FP**). One Technical Memo (**ITM**) is required for the second MiniLab. The FP presentations will be the scheduled at final exam time slot.

‡Log Books are due as noted, on Thursday at the end of your lab session. Log book entries will be graded once completed. For instance on January 30th the first minilab will be graded, on February 20th the first choice of Labs 1 and 2 will be graded, etc. By the time of grading all data reduction and analysis should be complete. GLBs will record one grade each, irrespective of the number of entries graded. Written Technical Reports/Memos are due by **5:00 pm** on the Friday of the week shown above. Turn them in by sliding under the lab door of 2256 SC. **Do not bring them to the Departmental Office.** Log books will be returned the following Friday from 11:30 am to 1:00 pm in the lab.

Labs: Description	**Duration**

Mini-labs - You will perform the following labs.

Mini-lab 1: Instrumentation Review	1 Lab Period
Mini-lab 2: Accuracy and Precision – Use of Gauge Blocks as a Local Standard	1 Lab Period

*Labs 1 and 2: Labs for General Concepts and Measurements Devices - You will complete **three** of the following labs, choosing at least one on thermo/fluids (TF) and one in dynamic systems (DS), and at least one from each of the Lab 1 and Lab 2 groups. Labs will be scheduled on a "first come first serve" basis.*

Note: Your first choice of Labs 1/2 has a more limited requirement on error analysis, since concepts are being introduced in class as the lab is developed, and is allocated 5 lab periods (2.5 weeks). Second and third Labs 1/2 choices require complete error analysis and are allocated 3 weeks.

Lab 1a: Wind Tunnel Testing Principles, and Lift and Drag Measurement (TF)	5/6 Lab Periods
Lab 1b: Cooling Tower Performance and Sensors for Thermal-Fluid Systems (TF)	5/6 Lab Periods
Lab 1c: "Isentropic" Blow-down Process and Discharge Coefficient (TF)	5/6 Lab Periods
Lab 1d: Vapor Drag Reduction on a Sphere (TF, in preparation)	5/6 Lab Periods
Lab 1e: Compressed Air Turbine Performance Measurement (TF)	5/6 Lab Periods
Lab 1f: Boiling Heat Transfer Paradox (TF)	5/6 Lab Periods
Lab 1g: Forced Pendulum and Chaotic Response (DS)	5/6 Lab Periods
Lab 2a: Dynamic Response of a Mass-Spring System with Damping (DS)	5/6 Lab Periods
Lab 2b: Dynamic Response of a Rotor with Shaft Imbalance (DS)	5/6 Lab Periods
Lab 2c: Driven Oscillations of a Rectilinear Mass-Spring Damper (DS)	5/6 Lab Periods
Lab 2d: Driven Oscillations of a Torsional Pendulum (DS)	5/6 Lab Periods
Lab 2e: Thermal System Response and Effective Heat Transfer Coefficient (TF)	5/6 Lab Periods
Lab 2f: Natural Convection and Boiling Curve for a Platinum Wire (TF)	5/6 Lab Periods
Lab 2g: Car Suspension Mechanism (DS)	5/6 Lab Periods

Laboratory Behavior and Practice

In view of their purpose, laboratories exhibit the potential to be hazardous. Delicate and expensive equipment demands that special precautions be taken to ensure proper operation and safety for the user. A few basic steps can be taken to make the laboratory safe and an enjoyable and productive experience. Some of these steps are listed below.

1. Keep all bottles and containers closed when not in use.
2. No excessive noise (loud talking, radios, etc.) are allowed as disturbance to others may easily occur.
3. Absolutely no smoking in laboratories.
4. Report immediately any defective or malfunctioning equipment. If a piece of equipment is broken, report it immediately. You are not penalized if a piece of equipment is broken.
5. Return all tools, equipment, and manuals to their proper place. Remember, you may want to use the item the next time.
6. Make sure all equipment, valves, lights, etc., are turned off when you leave the laboratory. However, do not turn off the computers and their accessories.

Laboratory and Classroom Behavior Expectations

Students are expected to behave professionally both in lectures and in the laboratory. Coming to class unprepared, apathetic, disrespectful and unmotivated shows a degree of unprofessionalism unacceptable for seniors about to graduate. Some guidance:

1. Read through the syllabus carefully to know what to expect in the course.
2. Read the material before the lectures and labs.
3. Reports, memos and logbooks should look professional and of good quality.
4. Follow a code of ethics.
5. Be scrupulously honest and show uncompromising integrity.
6. Show up for class either before class starts or on time.
7. Proofread your work before turning it in.
8. Do not include funny comments in your assignments.
9. Stay awake during class.
10. Spit out gum and turn off cell phones.
11. Do not read the newspaper or bring a laptop to the lectures.

LOG BOOK

The purpose of the **Log Book** is to record daily progress of experimental and other pertinent information related to the experiment. This information should contain sufficient information and commentary to enable reproduction of the experimental results at some future date. The **Log Book** can be used as evidence to establish patent rights for a new discovery. It may be needed to protect the researcher and to establish legal liability in a lawsuit. In some laboratories, the **Log Book** must be signed by someone who witnessed and understood the experiment.

The **Log Book** must be bound so as not to lose any relevant information. No pages are to be removed, or added unless clearly noted.

The **Log Book** should be brought to each laboratory period or meeting session in case some information is needed and/or is to be added. All entries should be dated, entrant name indicated, printed, neat, logical, in ink (to preserve longevity), entered at the time which the event took place, and original. Any pages that are left intentionally blank, including the back sides, should be marked as "Blank." If any material written in the **Log Book** is to be ignored, i.e., bad data, the material should be neatly crossed out and never erased or torn out. The **Log Book** is the working record of the experiment and recopying of information into the **Log Book** after the laboratory period is not desired. Corrections and crossed out material are normal, and a perfectly appearing **Log Book** may be suspect. Items such as computer generated listings and plots which are not conveniently placed in the **Log Book** should be neatly and securely placed in a notebook or 3-ring binder.

The **Log Book** is to be turned in Thursdays as indicated. The **Log Book** will be graded and then returned Friday.

Log Book Guidelines

The Log Book must accurately record the laboratory experiment. All handwriting must be entered in ink, and must be **clear and legible**. The readability of the Log Book will be improved if greater spacing is utilized in the written material.

Any material that is affixed to the Log Book (e.g. figures, charts, etc.) must be securely taped into the Log Book (tape at least opposite sides). After inserting material in this manner, the owner of the Log Book must sign his/her name such that part of the signature is on the attachment and part of it is on the original Log Book page. This ensures that nothing is added to/removed from the Log Book at a later date.

At the end of each lab session, everyone *must* have the lab TA sign his/her Log Book.

Format

HEADING (TITLE)

Experiment No. 0
Group: V

Workstation No. 2 (Continued)
Supervisor: John Doe

When a workstation is continued from a previous lab period, indicate this. Include the major heading that is being continued.

EXPERIMENT TITLE AND OBJECTIVE

Provide a title (see above) and brief summary of the objectives (no more than two or three sentences or several bullets) of the experiment.

PLANNED PROCEDURE

Do not copy the procedure from the Lab Manual. Try to summarize using only several sentences or bullets. This is a pre-mediated "plan of attack" that should be completed prior to starting the experiment. Modifications to this may be made in the “Actual Procedure and Findings” section, which is completed during the experiment.

INSTRUMENTATION AND LABORATORY ORIENTATION

Schematic diagram of the experimental set-up for each workstation is required for all experiments, except for Exp. No. 1. Be sure to label all components of the diagram. Use descriptive titles for figures (and tables).

ACTUAL PROCEDURE AND FINDINGS

The Lab Manual and experiment handouts do not provide a complete description of the procedure you might perform. Present here what your actual procedure was and what you found out in the process.

As you perform the experimental procedure you will have “Findings”. The “Actual Procedure and Findings” may include subheadings including the "Experimental Data", "Data Reduction", "Procedure Modifications", and "Discussion of the Results". Computer printed tables or figures can be "permanently" taped to the Log Book.

Calculations for data reduction should be explained in this section and the references that are utilized to obtain physical properties, theoretical models, etc. need to be cited. The Findings section (as well as the Conclusions) should be written in a technical manner. Avoid the use of

words like "good" when describing the experimental results, unless numerical values are included that quantify the meaning of "good". The Findings section is important and merits greater effort. As an example, discussion of the heated water workstation of Exp. No. 1d can compare the calculated energy which is required to heat the water compared to the measured value, and give possible reasons for the differences observed. Data Reduction should include sample calculations along with the data. Additional information regarding the procedure can be added including a step-by-step explanation followed and equipment settings. **Ask yourself whether or not you could repeat the experiment at a later date using just your Log Book.**

CONCLUSIONS

The data and analysis must support all findings and conclusions. The Conclusions section should summarize the main points of the lab and should not introduce any new concepts that have not been discussed in a previous section. The Conclusions section must state whether the objective of the experiment was achieved. This section proves that the purpose of the experiment was understood. The experimenter should include any recommendations for future experimenters.

Log Book Grading

BEFORE LAB (individual work): TOTAL POINT VALUE: 20

Prelab questions: These questions carry 10% of the grade of the lab, including logbook and memo/report grades. You have to read the material suggested in the write-ups and review past classes to properly answer these questions.

Title (1 point): *Lab title*

Team Members/Supervisor/Group Number (1 point):
Temperature (1 point):
Barometer Reading (1 point):
Humidity (1 point):

Objectives (5 points): *The objective of this lab is to _____, Etc.* Do not include educational onjectives!!!

Planned Procedure (5 points): A short summary of the steps that you plan to take in the lab. It should include all aspects of the lab (don't just focus on one portion of the lab)

- *A digital multimeter will be used to measure the voltage produced by a power supply.*
- *Etc.*

Equipment List (5 points): (Record serial numbers during lab)

Oscilloscope	*Model: Tektronix TDS 1002*	*S/N: C038204*
Digital Multimeter	*Model: HP 34401A*	*S/N: US36079920*
Power Supply	*Model: 6612C*	*S/N: 453746064*
Function Generator	*Model: HP 33120A*	*S/N: US36017794*
…		

DURING LAB TOTAL POINT VALUE: 40

Actual Procedure (20 points – 1 log book per group): This should be detailed! You do not need to include things like "Turn on power supply," but should include anything needed to repeat the lab using only your log book. Everyone should include the heading "Actual Procedure," and under the heading write "See John Doe's notebook" if the procedure is not written in your lab book that week

Results (20 points – everyone needs to have a copy in their lab book): Plots, tables, etc. exhibiting the raw data obtained in lab. Everyone needs to include the raw data from the lab in their individual lab book.

AFTER LAB (individual work) TOTAL POINT VALUE: 40

Analysis and Discussion (30 points): Analysis includes calculations performed using the raw data. Discussion includes any unexpected data or trends, explanations of the physics, etc.

Conclusions and Recommendations (10 points): Conclusions about how well the objectives were achieved, the overall results of the experiment, and recommendations for improvements.

Technical Reports

Presentation and report of engineering or scientific work are probably as important as the actual work. Credit for a discovery or development of new concepts cannot be received until the work has been described in a report or paper that is readily available for other people to read. It is often stated that engineers upon graduation will spend their first few months of work doing about 30 percent engineering and 70 percent writing. Other related statements are "graduates of engineering programs must have substantial communication skills if they are to function effectively in industry and government" and "engineering graduates often wish they had more training in communication skills in college." One goal of this course is to develop effective written and oral communication skills. This will be accomplished by requiring written technical reports for each experiment and an oral presentation by the group. Appendix A of Ref. [1] provides general guidelines for report writing.

In numerous environments, a report is written for a specific **audience**. Thus, it is important to first identify the intended audience (e.g., a supervisor as compared to a colleague) and to recognize the type and order of information the reader is seeking. The report format, therefore, varies. However, most reports include three essential elements: introduction, narrative, and conclusion. Remember that **brevity and clarity are important** and the report should be of high quality to be read. All reports should be written in the third person (e.g., use "the pressure was measured..." instead of "we measured the pressure...").

A good dictionary should be nearby when the report is being written. No excuses for misspelled words. Proof reading cannot be over-emphasized. If possible, have someone read the report for grammar, style, spelling, clarity, and typographical errors. Make sure nouns and verbs agree.

ABET, the accreditation board for college and university programs in applied science, computing, engineering, and technology, requires evaluation of reporting skills in terms of *Organization in Writing* (sequence of information, graphics, discussion and conclusions, design of contents) and *Writing Skills* (grammar, spelling, sentence clarity, syntax). These are graded in Experimental Engineering using the Technical Reports and reported to ABET. ***All students must have at least a Satisfactory grade in Organization in Writing and Writing Skills to pass the class***.

The report is limited to ten pages plus appendices, with the following format:

1 GRADE SHEET
2 TITLE, AUTHORS AND ABSTRACT
3 INTRODUCTION
4 EXPERIMENTAL CONSIDERATIONS
5 RESULTS AND DISCUSSION
    Error Analysis
6 CONCLUSIONS AND RECOMMENDATIONS
7 REFERENCES
8 APPENDICES

All material is to be written using computer word processing on double-spaced standard 8-1/2 x 11 in unlined paper. All margins (top, bottom, right and left) will be 1 inch. This allows space for grader's comments and marking. Any oversized sheets of paper that are necessary to the report (plots, figures, computer programs and listings, results, etc.) should be neatly folded and

easily unfolded and should not extend beyond the cited dimensions. No smaller or larger sheets are allowed. The entire report will be stapled in the upper left corner or with staples along the left-hand 11-inch-long side; stapler available at the MIE office. All pages must be numbered with the INTRODUCTION as page 1.

A. REPORT CONTENT

The contents of each section of the report are described briefly in the following discussion:

GRADE SHEET

This sheet is included at the end of this document and should be attached as the first page. Fill out the experiment number, title of report, date handed in, and author's name. Note the points awarded to each section.

TITLE AND AUTHORS

In the order shown, with appropriate spacing, include:

a) Title of report

b) Authors, group and affiliation

c) Date submitted

ABSTRACT

The abstract should report the basic accomplishments and attempt to entice the reader to read further. An abstract (or summary) should seldom be longer than one page and is typically around 200 words. The following items should be included:

a) Objective of work

b) Brief statement(s) on how objective was achieved (the work that was done)

c) Conclusions and recommendations are summarized (be quantitative!)

The abstract stands by itself. Note that equations or references do not, in general, appear in the abstract. The abstract should be written after the rest of the report has been completed. An **executive summary** is an extended abstract of up to about 500 words, and it may include an essential figure.

INTRODUCTION

The introduction places the work in perspective, i.e. cites relevance, motivation, some previous background, and, most importantly, the objectives of the work. **It should answer the question, "Why did you do what you did?"** It is convenient to introduce the objective as "The objectives of this study are...". It states the hypothesis and concepts tested. Remember that your objective IS NOT "to learn about this or that…" but to measure something that may help you discover or resolve a problem.

EXPERIMENTAL CONSIDERATIONS

The purpose of this section is to describe the experiment technique and how the experiment was performed. **It should answer the question, "What did you measure and how?"** This section should include a schematic diagram of the apparatus, important

measurements recorded, and method of data reduction procedure if it is uncommon or it lends credence to measurements. All figures and tables should be labeled with number and title (e.g. Figure 1. Schematic Diagram of Equipment). The figures are referred to by number in the text (e.g., "In Fig. 1, the....). See additional discussion of proper formatting of figures, tables, and equations below. You may choose to place tables and figures in appendices, rather than integrated into the text.

This section of the individual reports is used to evaluate the ABET criterion "Experimental Procedures," and ***students must have at least a Satisfactory grade to pass the class***.

RESULTS AND DISCUSSION

Experimental results in reduced form are presented and discussed in this section. **This section should answer the question, "What did you find?"** Any anomalies and regions of questionable data should be cited. General trends along with physical meaning are useful for explaining results. The results could be plotted or tabulated (if resulting tables are small), however, the former method is more readable. A graph should have labels and titles for the abscissa (independent) and ordinate (dependent) axes. Data points are generally plotted with symbols and may be connected by lines not passing through the symbol. **Error bars should always be shown in the plots!!** Results from an analysis are presented by solid, dashed, or other broken lines. No colored lines should be used as these are difficult to reproduce. Label all curves. The discussion should cite the important trends and findings, and should include uncertainty statements. See more discussion below on formatting of plots.

This section of the individual reports is used to evaluate the ABET criterion "Data Analysis," and ***students must have at least a Satisfactory grade to pass the class***.

Also, a detailed error analysis must be included in this section, identifying elemental errors and the procedures to obtain a final uncertainty. This subsection and the results from Exam I are used to evaluate the ABET criterion "Error Analysis." ***All students must have at least a Satisfactory grade to pass the class***.

CONCLUSIONS AND RECOMMENDATIONS

This section should be brief and concise. The conclusion should refer back to the objectives. The recommendations should indicate future work or improvement of experimental procedures. Maximum section length is two pages. **It should answer the question, "What did you find?"**

REFERENCES

Cite only articles, books or manuals used in the experiment and cited in the reports. References are a courtesy to recognize the work of others and serve as sources for further information for the reader. The references are listed in numerical order as cited in the text of the report (not necessarily alphabetic order). Sometimes, a bibliography may be included. As an example for reference citation, further reading on technical writing can be found in Appendix A of Ref. [1]. Example:

1. Figliola, R. S. and Beasley, D. E., *Theory and Design for Mechanical Measurements*, Third Ed., Wiley, 2000, pp. 509-515.

APPENDICES

Material that is somewhat bulky and does not necessarily contribute to the overall presentation of the report is placed in this section. Give the appendices titles; for example, "Appendix A: Tables" or "Appendix C: Example Calculations". Several items that may be included are:

- List of Nomenclature and Symbols Used: See example below
- Tabulated Data: Give the raw data in a neatly tabulated format. Also include any summarized results.
- Figures: if you choose not to place the figures in the text, you can place them in an appendix, but still have them in the proper order as they are referred to in your text.
- List of Equipment: See the LOG BOOK. Include the major pieces of equipment identified by name o should be identified.
- Methods: Discuss in greater detail how the experiment was performed, but do not give a minute by minute presentation.
- Error Analysis: Estimate the accuracy of all measurements. Give statistically meaningful results.
- Sample Calculation: Give a sample calculation including a unit analysis. Insert typical data into calculations.
- Theory: If possible, attempt to correlate measurements with a theoretical model.
- Computer Program: When a computer program is utilized, a listing with a representative case should be given.

B. FORMAT OF PLOTS, TABLES AND EQUATIONS

1. General things to remember about references, figures and tables

- References, figures and tables should be referred to and numbered in order of appearance.
- Make sure **all** figures and tables are referred to, don't just put some table or figure into your report.

2. Graph and Plot Rules of Thumb (for reports, memos and log books)

- X-axis for independent variable, Y-axis for dependent variable; y = f(x)
    - Label all axes on the outside of the axis borders; the format should be:
    - LABEL, symbol, units for example – " Stress σ, [MPa] " Label is in quotes …
    - Include important information inside your plot frame, such as -test conditions -assumptions -material type -data legends, etc., only when necessary.
- Provide an equation in the plot frame if: -analytical curve used and the equation is relevant -empirical curve is found that describes the data well, and, for example if it is a linear fit, don't just leave it as y = mx + b, instead use something like:

$$\text{Voltage (V)} = 10.23\ (\text{lbf}) + 0.02$$

- Provide a small sketch if it is helpful and necessary
- Place figure number and a descriptive title at the bottom of the figure, for example in Appendix A of see the figure below

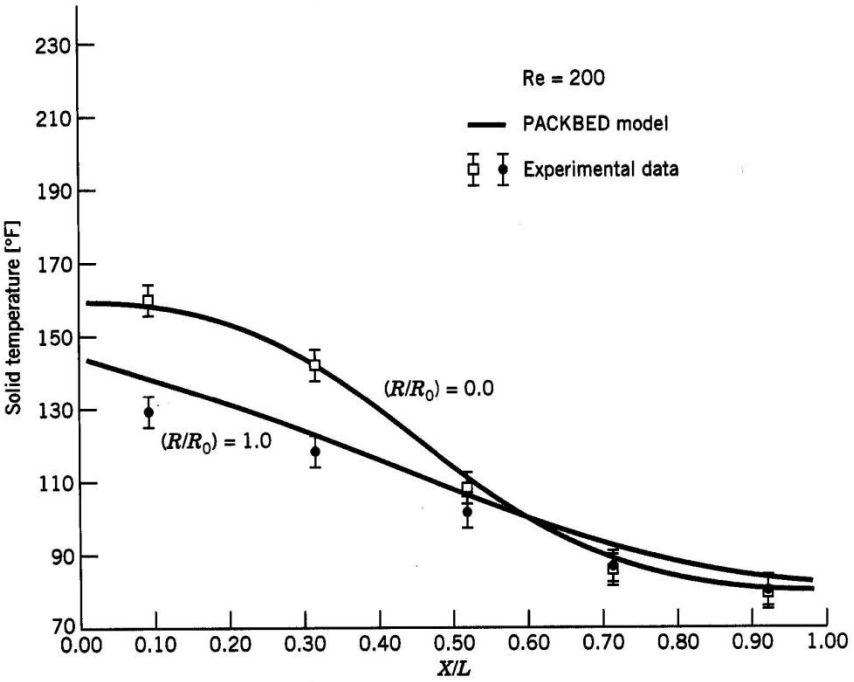

Figure A.1. Comparison of experimentally measured and computed results for axial temperature distributions for spheres of radius R in a thermal energy storage bed of radius R_0.

- For experimental data, even with empirical curves, always show data points using symbols and add error bars
- For analytical or theoretical curves (from equations) do not show symbols, use a line.
- If more than one symbol is used you must provide a legend (unless you identify the data or curve clearly using a title and arrow). If there is only one curve or data set, use no legend.
- Finally, ask yourself the following questions: Can the figure stand alone and tell the entire story by itself without any accompanying text? It should be able to… If it can, ask yourself, is it a "pretty" figure that uses:
    - -same font throughout -does the font match the text -effective use of capitalization and bold lettering -do all the plots of similar type and results look similar? -be consistent so as not to confuse the reader: once they understand one plot, and if other plots are presenting similar information and are consistent, they can be quickly and easily understood by the reader.

3. Table Format Rules of Thumb (for reports, memos and log books)

- Table number and descriptive title should be located **above** the table. Consider the example shown in Table A.1
- Use borders to properly separate headings and columns of data
- Clearly label all columns of data **including the units**

Table A.1 Characteristics of a Thermistor Anemometer in a Uniform Flow Field

Velocity [ft/s]	E[V]
0.467	3.137
0.950	3.240
2.13	3.617
3.20	3.811
3.33	3.876
4.25	3.985
5.00	4.141
6.67	4.299
8.33	4.484
10.0	4.635
12.0	4.780

- Keep raw data and reduced data separate to avoid confusion
- Can the table stand alone? Is it a "pretty" table that uses: -same font throughout -does the font match the text -effective use of capitalization and bold lettering -do all the tables of similar type and results look similar? -Consistency

4. Equations

Equations used and referred to in your work will be numbered sequentially in order of reference. The number for an equation will be in parentheses (X) and this number will be justified at the right hand margin as in the example equation below:

$$h_{nat} = 0.84\left(T_{surf} - T_{amb}\right)^{1/3} \tag{1}$$

Symbols or variables used in your equations will be defined. These definitions will be made either in the text with the equations, or in an appendix that contains your nomenclature. An example of defining the variables in your text is shown below:

"Where there is no spray or roll contact, a natural convection heat transfer coefficient correlation is used

$$h_{nat} = 0.84\left(T_{surf} - T_{amb}\right)^{1/3} \tag{2}$$

where h_{nat} is the natural convection heat transfer coefficient (W/m^{2}K), T_{surf} and T_{amb} are slab surface and ambient temperatures (K), respectively."

An example of nomenclature listing is:

NOMENCLATURE

c_p specific heat (kJ kg^{-1} K^{-1})

C mass concentration of an element (wt pct)

D_s mass diffusion coefficient in the solid ($m^2 s^{-1}$)

h_{spray} spray cooling heat transfer coefficient ($W m^{-2} K^{-1}$)

Δh latent heat ($kJ kg^{-1}$)

w* spray cooling flux ($L m^{-2} s^{-1}$)

x slab thickness dimension (m)

z casting direction, distance from meniscus (m)

Greek

κ partition coefficient (wt pct/wt pct)

λ_2 secondary dendrite arm spacing (m)

Subscripts

s solid

l liquid

Superscripts

i refers to the i-th chemical element

C. FINAL THOUGHTS AND RECOMMENDATIONS ON REPORTING WRITNG

A major emphasis of this course is the writing of a good technical report. It is unlikely that a good report can be prepared beginning just a day or two before the due date. Some suggestions are presented here to make the writing proceed smoothly.

Begin writing as soon as possible. The Introduction can be written after the lab period spent organizing and setting up the experiment. The Experimental Considerations section is the easiest one to write because it is just a description of what you did. The procedure for all members of a group should be very similar, but in each member's own wording. Make an outline of this section and have all group members agree to the outline.

A sample calculation for the appendix can be prepared as the data are reduced. As the data are reduced, the group can discuss the results. Do the results show what was anticipated, and if not can this be explained? Are any discrepancies between experiments just due to experimental error, or are they the result of some physical phenomena?

The Abstract is written last. Take key sentences and phrases from the rest of the report and put them together to form the abstract.

Proofreading the report is essential. Read forward to check for grammar and logic. Have someone else read the report to check for errors. The lab report should be thorough in its coverage of the experiment. The report should also be concise; excess material should be avoided.

Technical Memo Format

Many times in "real life" experimental situations, a full-scale formal technical report is not necessary, nor is it effective. A brief "Technical Memo" is used. This technical memorandum, sometimes called an executive summary, is less formal than the full report. It is not a permanent record of the work, and hence does not include all the details and data that should be included in a formal report. It can be a very common way of disseminating information within an organization. In particular, it is used to summarize the results of technical work to non-technical colleagues. According to Wheeler and Ganji [1] some of the common uses are:

1 Reporting intermediate results of a project (progress reports)
2 Reporting final results in a preliminary form prior to the issuance of a formal report
3 Reporting the results of studies or evaluations for which a permanent record is not required.

The format below is suggested for your memo (**note: limit your text to one page!**):

MEMO

To: T.A.'s Name **From:** Your Name (followed by Group ID included in parenthesis) **Date:** Month, Day, Year **Subject:** Experiment No. 3, Dynamic Sensing

The key points, features and content of your technical memo are:

- The Memo should be **limited to one-page (points will be deducted if it is longer!)**, single column and single-spaced.
- The Memo should be an executive summary of the results.
- The **Objectives, Experimental Considerations, Results, and Conclusions and Recommendations should be included** in the Memo. Your memo should make clear the purpose of the work, the results of the work, and the significance of the results.
- One page of figures or tables can be appended to the Memo, if it is necessary to report the findings. These are called “Attachments”, label them Attachment A, Attachment B, and so on.
- **Reference the Log Book for specific analysis and results (give page number!)**.

The Memo will be evaluated using the Grade Sheet. Attach a copy of Grade Sheet to your Memo report.

[1] Wheeler, A., and Ganji, A., *Introduction to Engineering Experimentation*, Prentice Hall, 1996, p. 381.

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TECHNICAL REPORT GRADE SHEET

Experiment Number:	Title:
Date:	Name:

Report Section	Points Max	Grade	ABET Grade (0-20)
TITLE PAGE	**2**		
ABSTRACT	**5**		
INTRODUCTION	**11**		
EXPERIMENTAL CONSIDERATIONS	**20**		
RESULTS AND DISCUSSION	**25**		
Error Analysis			
CONCLUSIONS AND RECOMMENDATIONS	**10**		
REFERENCES	**2**		
APPENDICES	**10**		
DEGREE OF DIFFICULTY, ORIGINALITY, CREATIVITY	**15**		
LATE REPORT (-10 points per day)			
Organization in writing (ABET Grade/2-10)			
Writing skills (ABET Grade/2-10)			
TOTAL SCORE	**100**		

(PLEASE ATTACH A COPY OF THIS GRADE SHEET PAGE TO THE FRONT OF YOUR TECHNICAL REPORTS)

Report Grading

		Points
	Title Page	**2**
1	Minor error	-1
2	Multiple errors	-2
	Abstract	**5**
3	No brief statement on procedure/equipment	-2
4	No objectives	-3
5	Bulleted objectives	-2
6	Wrong focus of objectives	-1
7	No quantitative results	-2
8	No mention of error	-1
9	A lot of irrelevant information	-1
10	No conclusions	-1
	Introduction	**11**
14	No motivation/relevance cited	-2
15	No previous background cited	-2
16	-No outside theory	-4
17	No objectives cited	-4
	Experimental Considerations	**20**
18	No explanation of measurements taken (repititions, methods, etc)	-8
19	No mention of equipment type	-5
20	No comment on accuracy of the equipment	-2
21	No schematic diagram of test apparatus	-1
22	Improperly labeled figures/tables, etc (if applicable)	-1/occurrence up to -5
23	Procedure not detailed enough that it could be repeated	-10
24	No comment on error analysis	-2
	Results/Discussion	**25**
25	No experimental results in reduced form (plot, etc)	-15
26	Excessive experimental results in tabular form	-5
27	No comment on anomalies in data (if applicable)	-5
28	Equations improperly inserted (PASTED), and labeled (or inserted/labeled in appendix and referred to)	-1/occurrence up to -5
29	Equation variables not defined	-1/equation up to -5
30	Too many significant figures	-1/occurrence up to -5
31	Data incorrectly labeled/incorrect units	-1/occurrence up to -10
32	No error analysis	-20
33	- No elemental errors	-8
34	- No error propagation	-8
35	- Reported errors, but no formulas	-1/equation up to -5
36	- Reported errors, incorrect formulas	-1/equation up to -5
37	In depth attempt made at analysis/discussion, but incorrect theory	-8 MAX
38	No in depth attempt made at analysis/discussion	-15
	Plots/Figures - Either in Results or in Appendix	
39	Variables not on proper axes	-1/occurrence up to -5
40	Axes missing labels	-1/occurrence up to -5
41	Axes missing units	-1/occurrence up to -5
42	Plots/Data is not readable	-1/occurrence up to -5
	Conclusions/Recommendations	**10**
43	Not concise	-2
44	No mention of objectives	-3
45	Not specific, too vague	-5

46	No brief, quantitative conclusions	-5
47	No recommendations	-3
	References	**2**
48	Not properly formatted	-1
49	No references	-1
50	Citations missing within text	-1
	Appendices	**10**
51	Appendices not properly labeled	-1
52	Appendices not well organized	-1
53	Figures not in order as referenced in text	-1/occurrence up to -5
54	Figures/data not referenced in text	-1/occurrence up to -5
55	Equations improperly inserted (not PASTED), and labeled (or inserted/labeled in appendix and referred to)	-1/occurrence up to -5
56	Too many significant figures	-1/occurrence up to -5
57	Data incorrectly labeled/incorrect units	-1/occurrence up to -5
	Plots/Figures - Either in Results or in Appendix	
58	Variables not on proper axes	-1/occurrence up to -5
59	Axes missing labels	-1/occurrence up to -5
60	Axes missing units	-1/occurrence up to -5
61	Plots/Data is not readable	-1/occurrence up to -5
62	Excessive experimental results in tabular form	-5
	Degree of Difficulty, Originality, Creativity	**15**
63	Things copied directly from lab hand out	
64	No attempt to include outside theory to aid explanation	
65	No attempt to explain beyond bare minimum requirement of lab	
66	Degree of effort seems minimal	
	*If lab was exceedingly difficult, full points may be awarded here to make up for incorrect data analysis	
	Spelling/Grammatical Errors	
67	Third person usage	-1/occurrence up to -5
68	No indentation	-2
69	Spelling/Grammar errors	-1/occurrence up to -10

This page can be found in
http://www.engineering.uiowa.edu/~expeng/Grade%20Forms/Tech_Memo_Grade_Sheet.pdf

TECHNICAL MEMO GRADE SHEET
058:080 Experimental Engineering

Title: _____

Name(s): _____

Section: _____ Group: _____

Lab Number: _____ Date: _____

Report Section:	**Points:**	**Grade:**
OBJECTIVES State the hypothesis and concepts tested.	10	_____
EXPERIMENTAL CONSIDERATIONS Provide the method used to perform the experiment.	20	_____
RESULTS AND DISCUSSION Display findings and trends followed. Discuss important observations, unexpected trends and uncertainties.	40	_____
CONCLUSIONS AND RECOMMENDATIONS How well were all the objectives achieved?	30	_____
PAGE LIMIT -10 points for each page exceeding the limit	0	_____
SPELLING AND GRAMMATICAL ERRORS -1 point per error	0	_____
GRADE SHEET AND FORMATTING ERRORS -1 point per error	0	_____
TOTAL SCORE	**100**	_____

(THIS GRADE SHEET MUST BE ATTACHED TO THE FRONT OF ALL YOUR TECHNICAL MEMOS)