

COURSE ASSESSMENT REPORT

**ROY G. PERRY COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**

ASSESSMENT REPORT COVER PAGE

**MCEG 3101 MEASUREMENT AND
INSTRUMENTATION LABORATORY**

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Dr. Chang Duan

Revised: 5/20/2022

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 - 5.1 Assignments assessing students' ability to conduct experiments (outcome "6.2") and ability to analyze and interpret experiment data (outcome "6.3") and draw appropriate conclusions and recommendations (outcome "6.4")

Detailed Course Syllabus
(Distributed to Students at the beginning of the Semester)
ABET Outcomes measured using course should be
explicitly listed in the syllabus

Prairie View A&M University
Department of Mechanical Engineering
MCEG 3101 Measurement and Instrumentation Laboratory
Spring Semester 2022

Course Title	Measurement Laboratory
Course Prefix & No	MCEG 3101
Section	P01
Credit	1 Credit Hour
Instructor Name	Dr. Chang Duan
Office Location	C. L. Wilson Engineering Building Room 105H
Office Phone	936-261-9954
Fax	936-261-9969
Email Address	chduan@pvamu.edu
U.S. Postal Address	Prairie View A&M University P.O. Box 519, Mal Stop 2525 Prairie View, TX 77446
Office Hours	In-office: Monday, Wednesday 9 – 11 am Virtually (via Zoom): Tuesday, Thursday 9 – 11 am
Course Location	Gilchrist Engineering Bldg 109
Class Days & Times	Wednesday: 2:00 – 4:50 PM
Catalog Description	MCEG 3101. Measurement and Instrumentation Laboratory. Credit 1 semester hour. The scope of this course includes fundamentals in measurement theory, statistical analysis of experimental data, uncertainty, accuracy assessments, calibration techniques and robotics. The course includes the use and applications of instruments for measuring area, pressure, time, speed, temperature, strain, hardness, and deflection.
Pre-requisites	PHYS 2513/2325, PHYS 2511/2125, PHYS 2521/2126
Required Textbook	Measurement Laboratory Manual by Paul O. Biney

College of Engineering Textbook Policy – Students MUST acquire the required textbook that is listed on the course syllabus for this course. The textbook must be acquired by the 10th class day. Students are not allowed to share textbooks with students who are currently registered in the same class. Failure to acquire (or show proof of purchase) the required textbook by the 10th class day will result in the student being administratively dropped from the course. The University will assess financial obligations for the course to the student as with any other dropped class according to the fee schedule as well as your financial aid may be affected.

If you are not financially able to purchase a required textbook for an engineering course prior to the 10th class day, you may apply to the College of Engineering Textbook Fund for a textbook voucher. The voucher can only be used at the Campus Bookstore. This voucher is a loan and must be paid back to the College of Engineering prior to the start of pre-registration for the coming semester. If the loan is not repaid, a hold will be placed on your account. Additional information and application materials can be obtained from the Assistant Dean's Office

Recommended Text	Experimental Methods for Engineers by J. P. Holman, 7 th Edition, McGraw Hill, 2001
Access to Learning Resources:	PVAMU Library: Phone: (936) 261-1500; web: https://www.pvamu.edu/library/
Course Goals or Overview	The Goals of this course are to (1) introduce the fundamentals in measurement theory, statistical analysis of experimental data, uncertainty, accuracy assessments, and calibration techniques; (2) introduce students to the use and applications of instruments for measuring area, pressure, time, speed, temperature, strain, hardness, and deflection; and (3) introduce students to the analysis of experimental data, interpretation of experimental results and preparation of scientific reports. This course also introduces students to the concept of life-long learning.
Course Outcomes/Objectives	On completion of this course, the students will be able to • utilize various instruments for mechanical measurements, • determine the uncertainty in the dependent variables resulting from the uncertainty in the independent variables using statistical analysis, • conduct experiments, • analyze and interpret experimental data. Students will also be able to use other resources to further their understanding of concepts through life-long learning.
Course Requirements & Evaluation Methods	This course will utilize the instruments to determine student grades and proficiency of the learning outcomes for the course. Requiring students to read ahead of time the theory and method for analyzing the experiments to be performed
Laboratory Reports:	Requiring students to write a detailed technical report following normal accepted standards to describe the method used to conduct the experiment, detailed analysis of the data, and interpretation of the results.
Class Attendance:	Daily attendance and participation in class discussion required.

Grading Matrix

Instrument	Total (%)
Quizzes	15
Ability to Conduct Experiment	10
Ability to Analyze Experimental Data	20
Ability to Interpret Experimental Data	20
Tests	35
Total:	100

Grade	A = 90 - 100
Determination	B = 80 - 89
	C = 70 - 79
	D = 60 - 69
	F = 0 - 59

Note: The instructor reserves the right to alter it during the semester.

Course Policy

Academic Integrity

Academic dishonesty of any sort (plagiarism, cheating, fabrication or facilitation) is prohibited under any circumstance. Any detected actions of dishonesty will cause the failure of the class directly.

Assignments & Due Dates

Lab reports will be submitted online by the due dates. **Late submission will be charged a 20% penalty for each day late – weekend days do count.** Circumstances beyond your control (i.e. illness, weather, etc) will be considered as required.

Attendance

Class attendance is mandatory. You should notify the instructor if you cannot attend the class. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in the assignment of a grade of "F."

Labs

No makeup labs will be given. You will be expected to conduct the lab in the allotted time period on the lab day.

Exams

There will be a mid-term exam and a final exam. No makeup test will be given. In case the exams are not given, your average in all of the labs will be used for your exam score.

Question/concern about grades

All discussion about grades excluding final exam grade should happen before final exam. Questions about grade of quizzes, homework, exams should be brought up within one week after they are graded and given back to you.

Important Dates

<https://www.pvamu.edu/registrar/academic-calendars/spring-2022-16-week-session/>

How Mechanical Engineering Courses meet Department Objectives & ABET Criterion 3

Specific objectives of the Mechanical Engineering Program are to produce graduates who will:

1. have the necessary knowledge and skills to enable them have successful careers in mechanical

- engineering and related fields;
2. have leadership skills to advance their careers through increasing levels of responsibilities and leadership;
3. have the necessary educational background to successfully pursue graduate or advanced professional degrees and continuing professional development, and
4. actively participate in professional and community services.

ABET Criterion 3: Program Outcomes and Assessment

Engineering Programs must demonstrate that their graduates have:

- (1) the ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics;
- (2) the ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factor;
- (3) the ability to communicate effectively with a range of audiences;
- (4) the ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts;
- (5) the ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives;
- (6) ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions;
- (7) the ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Program Outcomes

Covered by Course Program Outcomes 6 and 7, as defined above

Program Outcomes

Measured by Course Program outcomes 6 as defined above

Data Used in Assessing

Outcomes in Course

1.	Quizzes	
		2. Laboratory Report
		3. Class Participation
		4. Life-long learning assignment

Data Used to Show

Student Proficiency

in Outcomes

1. Samples of student work in a Binder
2. Excel Spreadsheet showing student performance and class average in outcomes
3. End of Semester Course Assessment report

TENTATIVE CLASS/LAB SCHEDULE

Week	Lecture and Lab
1	Syllabus Laboratory safety rules & lab report format
2	Theory: Statistical Analysis of Experimental Data
3	Experiment 1: Statistical Analysis of Experimental Data: (1) Length measurement with Micrometer.
4	Theory : Statistical Analysis and Chauvenets Criterion for Rejecting Data
5	Experiment 2: Statistical Analysis of Experimental Data: (1) Length measurement with Vernier Caliper. (2) Area measurement using a Planimeter.
6	Theory: Pressure Measurement and Pressure Gauge Calibration using dead Weight Tester
7	Mid-term Exam
8	Experiment 3: Pressure Gauge Calibration using dead Weight Tester
9	Theory: Simple Harmonic Motion
10	Experiment 4: Statistical Analysis of Experimental Data: Local gravitational acceleration measurement using a simple pendulum.
11	Theory: Sonar Sensor Calibration
12	Experiment 5: Sonar Sensor Calibration
13	Theory: Strain Gauge and Wheatstone Bridge
14	Experiment 6: Strain Measurement using Strain Gauge

Student Support and Success

John B. Coleman Library

The John B. Coleman Library's mission is to enhance the scholarly pursuit of knowledge, to foster intellectual curiosity, and to promote life-long learning and research through our innovative services, resources, and cultural programs, which support the Prairie View A&M University's global mission of teaching, service, and research. It maintains library collections and access both on campus, online, and through local agreements to further the educational goals of students and faculty. Website: <https://www.pvamu.edu/library/>; Phone: 936-261-1500

Academic Advising Services

Academic Advising Services offers students a variety of services that contributes to student success and leads towards graduation. We assist students with understanding university policies and procedures that affect academic progress. We support the early alert program to help students get connected to success early in the semester. We help refer students to the appropriate academic support services when they are unsure of the best resource for their needs. Faculty advisors support some students in their respective colleges. Your faculty advisor can be identified in PantherTracks. Advisors with Academic Advising Services are available to all students. We are located across campus. Find your advisor's location by academic major at www.pvamu.edu/advising. Phone: 936-261-5911

The University Tutoring Center

The University Tutoring Center (UTC) offers free tutoring and academic support to all registered PVAMU students. The mission of the UTC is to help provide a solid academic foundation that enables students to become confident, capable, independent learners. Competent and caring staff and peer tutors guide students in identifying, acquiring, and enhancing the knowledge, skills, and attitudes needed to reach their desired goals. Tutoring and academic support are offered face-to-face in the UTC, in virtual face-to-face sessions (<https://www.pvamu.edu/student-success/sass/university-tutoring-center/>), and through online sessions (<https://www.pvamu.edu/pvplace/>). Other support services available for students include Supplemental Instruction, Study Break, Academic Success Workshops, and Algebra Study Jam. Location: J. B. Coleman Library, Rm. 307; Phone: 936-261-1561; Email: pvtutoring@pvamu.edu; Website: <https://www.pvamu.edu/student-success/sass/university-tutoring-center/>

Writing Center

The Writing Center provides well-trained peer tutors to assist students with writing assignments at any stage of the writing process. Tutors help students with various writing tasks from understanding assignments, brainstorming, drafting, revising, editing, researching, and integrating sources. Students have free access to Grammarly online writing assistance. Grammarly is an automated proofreading and plagiarism detection tool. Students must register for Grammarly by using their student email address. In addition, students have access to face-to-face and virtual tutoring services either asynchronously via email or synchronously via Zoom. Location: J. B. Coleman Library, Rm. 209; Phone: 936-261-3724; Website: <https://www.pvamu.edu/student-success/writing-center/>; Grammarly Registration: <https://www.grammarly.com/enterprise/signup>

Academic Early Alert

Academic Early Alert is a proactive system of communication and collaboration between faculty, academic advisors, and PVAMU students that is designed to support student success by promptly identifying issues and allowing for intervention. Academic Early Alerts help students by providing a central location to schedule advising appointments, view advisor contact information, and request assistance. Students who recognize that they have a problem that is negatively affecting their academic performance or ability to continue school may self-refer an Academic Early Alert. To do so, students will log in to PV Place and click on Academic Early Alert on the left sidebar. Phone: 936-261-5902; Website: <https://www.pvamu.edu/student-success/early-alert/>

Student Counseling Services

The Student Counseling Services unit offers a range of services and programs to assist students in maximizing their potential for success: short-term individual, couples, and group counseling, as well as

crisis intervention, outreach, consultation, and referral services. The staff is licensed by the State of Texas and assists students who are dealing with academic skills concerns, situational crises, adjustment problems, and emotional difficulties. Information shared with the staff is treated confidentially and in accordance with Texas State Law. Location: Hobart Taylor, 2nd floor; Phone: 936-261-3564; Website: <https://www.pvamu.edu/healthservices/student-counseling-services/>

Office of Testing Services

Testing Services serves to create opportunities by offering a suite of exams that aid in the students' academic and professional success. Currently, we administer entrance (HESI A2), college readiness (TSI assessment), Prior Learning (CLEP, DSST), and proctored exams. Location: Wilhelmina Delco, 3rd Floor, Rm. 305; Phone: 936-261-3627; Email: aetesting@pvamu.edu; Website: www.pvamu.edu/testing

Office of Diagnostic Testing and Disability Services

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, contact the Office of Disability Services. As a federally-mandated educational support unit, the Office of Disability Services serves as the repository for confidential disability files for faculty, staff, and students. For persons with a disability, the Office develops individualized ADA letters of request for accommodations. Other services include learning style inventories, awareness workshops, accessibility pathways, webinars, computer laboratory with adapted hard and software, adapted furniture, proctoring non-standardized test administrations, ASL interpreters, ALDs, digital recorders, Livescribe, and a comprehensive referral network across campus and the broader community. Location: Hobart Taylor, Rm. 1D128; Phone: 936-261-3583; Website: <https://www.pvamu.edu/disabilityservices/>

Center for Instructional Innovation and Technology Services (CIITS)

Distance Learning, also referred to as Distance Education, is the employment of alternative instructional delivery methods to extend programs and services to persons unable to attend college in the traditional manner. The Center for Instructional Innovation and Technology Services (CIITS) supports student learning through online, hybrid, web-assist, and 2-way video course delivery. For more details and contact information, visit:

<https://www.pvamu.edu/dlearning/distance-learning-2-2/students-2/>; Phone: 936-261-3283

Veteran Affairs

Veterans Services works with student veterans, current military and military dependents to support their transition to the college environment and continued persistence to graduation. The Office coordinates and certifies benefits for both the G.I. Bill and the Texas Hazlewood Act. Location: Evans Hall, Rm. 102; Phone: 936-261-3563; Website: <https://www.pvamu.edu/sa/departments/veteranaffairs/>

Office for Student Engagement

The Office for Student Engagement delivers comprehensive programs and services designed to meet the co-curricular needs of students. The Office implements inclusive and accessible programs and services that enhance student development through exposure to and participation in diverse and relevant social, cultural, intellectual, recreational, community service, leadership development, and campus governance. Location: Memorial Student Center, Rm. 221; Phone: 936-261-1340; Website: <https://www.pvamu.edu/studentengagement/>

Career Services

Career Services supports students through professional development, career readiness, and placement and employment assistance. The Office provides one-on-one career coaching, interview preparation, resume and letter writing, and career exploration workshops and seminars. Services are provided for students at the Northwest Houston Center and College of Nursing in the Medical Center twice a month or on a requested basis. Distance Learning students are encouraged to visit the Career Services website for information regarding services provided. Location: Anderson Hall, 2nd floor; Phone: 936-261-3570; Website: <https://www.pvamu.edu/careerservices/>

University Rules and Procedures

Academic Misconduct

Academic dishonesty is defined as any form of cheating or dishonesty that has the effect or intent of interfering with any academic exercise or fair evaluation of a student's performance. The college faculty can provide additional information, particularly related to a specific course, laboratory, or assignment.

You are expected to practice academic honesty in every aspect of this course and all other courses. Make sure you are familiar with the *University Administrative Guidelines on Academic Integrity*, which can be found on the [Academic Integrity webpage](#). Students who engage in academic misconduct are subject to university disciplinary procedures. As listed in the *University Administrative Guidelines on Academic Integrity*, the University Online Catalog, and the Student Code of Conduct, the following are examples of prohibited conduct. This list is not designed to be all-inclusive or exhaustive. In addition to academic sanctions, any student found to have committed academic misconduct that is also a violation of criminal law may also be subject to disciplinary review and action by the Office of Student Conduct (as outlined in the Student Code of Conduct).

Forms of Academic Dishonesty:

1. Cheating: Deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not learned, giving or receiving aid unauthorized by the instructor on assignments or examinations. Examples: unauthorized use of notes for a test; using a "cheat sheet" on a quiz or exam; any alteration made on a graded test or exam which is then resubmitted to the teacher;
2. Plagiarism: Careless or deliberate use of the work or the ideas of another; representation of another's work, words, ideas, or data as your own without permission or appropriate acknowledgment. Examples: copying another's paper or answers, failure to identify information or essays from the internet and submitting or representing it as your own; submitting an assignment which has been partially or wholly done by another and claiming it as yours; not properly acknowledging a source which has been summarized or paraphrased in your work; failure to acknowledge the use of another's words with quotation marks;
3. Collusion: When more than one student or person contributes to a piece of work that is submitted as the work of an individual;
4. Conspiracy: Agreeing with one or more persons to commit an act of academic/scholastic dishonesty; and
5. Multiple Submission: Submission of work from one course to satisfy a requirement in another course without explicit permission. Example: using a paper prepared and graded for credit in one course to fulfill a requirement and receive credit in a different course.

Nonacademic Misconduct

The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with either (1) the instructor's ability to conduct the class, (2) the inability of other students to profit from the instructional program, or (3) campus behavior that interferes with the rights of others will not be tolerated. An individual engaging in such disruptive behavior may be subject to disciplinary action. The Office of Student Conduct will adjudicate such incidents under nonacademic procedures.

Sexual Misconduct

Sexual harassment of students and employees at Prairie View A&M University is unacceptable and will not be tolerated. Any member of the university community violating the university's sexual harassment policy will be subject to disciplinary action. In accordance with the Texas A&M University System guidelines, your instructor is obligated to report to the Office of Title IX Compliance (titleixteam@pvamu.edu) any instance of sexual misconduct involving a student, which includes sexual assault, stalking, dating violence, domestic violence, and sexual harassment, about which the instructor becomes aware during this course through writing, discussion, or personal disclosure. The faculty and staff of PVAMU actively strive to provide a learning, working, and living environment that promotes

respect that is free from sexual misconduct, discrimination, and all forms of violence. If students, faculty, or staff would like assistance or have questions, they may contact the Title IX Coordinator at 936-261-2144 or titleixteam@pvamu.edu. More information can be found at www.pvamu.edu/titleix, including confidential resources available on campus.

Pregnancy, Pregnancy-related, and Parenting Accommodations

Title IX of the Education Amendments of 1972 prohibits sex discrimination, which includes discrimination based on pregnancy, marital status, or parental status. Students seeking accommodations related to pregnancy, pregnancy-related conditions, or parenting (reasonably immediate postpartum period) are encouraged to contact Student Disability Services or the Dean of Students' Office for additional information and to request accommodations.

Non-Discrimination Statement

Prairie View A&M University does not discriminate on the basis of race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation, or gender identity in its programs and activities. The University is committed to supporting students and complying with The Texas A&M University System non-discrimination policy. It seeks to establish an environment that is free of bias, discrimination, and harassment. If you experience an incident of discrimination or harassment, we encourage you to report it. If you would like to speak with someone who may be able to afford you privacy or confidentiality, there are individuals who can meet with you. The Director of Equal Opportunity & Diversity has been designated to handle inquiries regarding the non-discrimination policies and can be reached at Harrington Science Building, Suite 109 or by phone at 936-261-1744 or 1792.

Class Attendance Policy (See the University Online Catalog for Full Attendance Policy)

Prairie View A&M University requires regular class attendance. Attending all classes supports the full academic development of each learner, whether classes are taught with the instructor physically present or via distance learning technologies such as interactive video and/or the internet. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in the assignment of a grade of "F." Absences are accumulated beginning with the first day of class during regular semesters and summer terms. Each faculty member will include the University's attendance policy in each course syllabus.

Student Academic Appeals Process

Authority and responsibility for assigning grades to students rest with the faculty. However, in those instances where students believe that miscommunication, errors, or unfairness of any kind may have adversely affected the instructor's assessment of their academic performance, the student has a right to appeal by the procedure listed in the University Online Catalog and by doing so within thirty days of receiving the grade or experiencing any other problematic academic event that prompted the complaint.

Technical Considerations

Minimum Recommended Hardware and Software:

- Intel PC or Laptop with Windows 10 or later version; Mac with OS High Sierra*
- Smartphone or iPad/Tablet with Wi-Fi*
- High-speed Internet access
- 8 GB Memory
- Hard drive with 320 GB storage space
- 15" monitor, 800x600, color or 16 bit
- Sound card w/speakers
- Microphone and recording software
- Keyboard & mouse
- Most current version of Google Chrome, Safari, or Firefox

Note: Be sure to enable Java & pop-ups in the Web browser preferences

* Smartphones, Google Chrome books, and Android tablets may not be supported. iPads are the only tablets supported.

Participants should have a basic proficiency of the following computer skills:

- Sending and receiving email
- A working knowledge of the Internet
- Microsoft Word (or a program convertible to Word)
- Acrobat PDF Reader
- Windows or Mac OS
- Video conferencing software

Netiquette (online etiquette)

Students are expected to participate in all discussions and virtual classroom chats as directed. Students are to be respectful and courteous to others on discussion boards. Foul or abusive language will not be tolerated. Do not use ALL CAPS for communicating to others AS IT CAN BE INTERPRETED AS YELLING. Avoid slang terms such as "wassup?" and texting abbreviations such as "u" instead of "you." Limit and possibly avoid the use of emoticons. Be cautious when using humor or sarcasm as tone is sometimes lost in an email or discussion post, and the message might be taken seriously or sound offensive.

Video Conferencing Etiquette

When using Zoom, WebEx, or other video conferencing tools, confirm the visible area is tidy, clear of background clutter, inappropriate or offensive posters, and other distractions. Ensure you dress appropriately and avoid using high traffic or noisy areas. Stay muted when you are not speaking and avoid eating/drinking during the session. Before the class session begins, test audio, video, and lighting to alleviate technology issues.

Technical Support

Students should go to <https://mypassword.pvamu.edu/> if they have password issues. The page will provide instructions for resetting passwords and contact information if login issues persist. For other technical questions regarding eCourses, call the Center for Instructional Innovation and Technology Services at 936-261-3283 or email ciits@pvamu.edu.

Communication Expectations and Standards

Emails or discussion postings will receive a response from the instructor, usually in less than 48 hours. Urgent emails should be marked as such. Check regularly for responses.

Discussion Requirement

Online courses often require minimal to no face-to-face meetings. However, conversations about the readings, lectures, materials, and other aspects of the course can occur in a seminar fashion. The use of the discussion board will accomplish this. The instructor will determine the exact use of discussion boards.

It is strongly suggested that students type their discussion postings in a word processing application such as Word and save it to their PC or a removable drive before posting to the discussion board. This is important for two reasons: 1) If for some reason your discussion responses are lost in your online course, you will have another copy; 2) Grammatical errors can be greatly minimized by the use of the spell-and-grammar check functions in word processing applications. Once the post(s) have been typed and corrected in the word processing application, copy and paste to the discussion board.

COVID-19 Campus Safety Measures

To promote public safety and protect students, faculty, and staff during the coronavirus pandemic, PVAMU has adopted policies and practices to limit virus transmission.

- **Self-monitoring** - Students should follow CDC recommendations for self-monitoring. Students who have a fever or exhibit symptoms of COVID-19 should participate in class remotely and should not participate in face-to-face instruction.

- **Face Coverings** - Face coverings (cloth face covering, surgical mask, etc.) are recommended in classrooms, teaching laboratories, common spaces such as lobbies and hallways, public study spaces, libraries, academic resource, and support offices, and outdoor spaces where 6 feet of physical distancing is challenging to maintain reliably.
- **Physical Distancing** - Physical distancing should be maintained between students, instructors, and others in course and course-related activities where possible.
- **Personal Illness and Quarantine** - Students required to quarantine are to participate in courses and course-related activities remotely and must not attend face-to-face course activities. Students should notify their instructors of the quarantine requirement. Students under quarantine are expected to participate in courses and complete graded work unless they have symptoms that are too severe to participate in course activities. Students experiencing personal injury or illness that is too severe for the student to attend class qualify for an excused absence. To receive an excused absence, students must provide appropriate documentation to the Office for Student Conduct, studentconduct@pvamu.edu.

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



MCEG 3101 MEASUREMENT LABORATORY

Spring 2022 Section P01

LABORATORY REPORT ON

“Measurement Using Micrometers and Statistical Analysis of Data”

**Conducted on
February 02, 2022**

Submitted by

**On
February 16, 2022**

To

**Dr. Chang Duan
*Measurement Laboratory Instructor***

MECHANICAL ENGINEERING DEPARTMENT
MEASUREMENT LABORATORY
LABORATORY GRADING SHEET
 SPRING 2022 SECTION P01

Title of Experiment: _____

Name: _____

Date Lab was Performed: _____

Report Due Date: _____

<i>Ability to Conduct Experiments</i>	MAX	Your Score	Comments
Ability to demonstrate general lab safety (by your conduct and observations).	3		
Ability to follow the procedure and properly rephrasing the procedure to reflect what you did during the experiment.	7		
Ability to demonstrate knowledge of how equipment function, their limitations, and the uncertainty associated with reading the instruments.	5		
Ability to collect and record the raw data using appropriate units of measurement and identify the dependent and independent variables in the experiment.	5		
Total for Ability to Conduct Experiments	20		
Percentage for this Performance Criteria			
<i>Ability to Analyze and Interpret experimental Data in a Formal Report</i>			
Report format (Ability to properly format and present a technical report)			
Front end of report	4		
General report format	4		
Provides appropriate abstracts for the experimental report	5		
Theory and equations for experimental and theoretical analysis of experimental data especially when requested for	5		
Ability to analyze the data using appropriate software to generate the required parameters using consistent units and significant figures.	22		
Use of statistical analysis as needed including uncertainty analysis	5		
Ability to present the data (raw /derived) in tabular and graphical form to meet the objectives and to aid in interpretation.	14		
Ability to discuss the raw and derived data/graphs and assess the validity of the results in relation to the underlying theory and expected trends.	14		
Ability to draw appropriate and reasonable conclusions in relations to each of the experimental objectives. One conclusion statement for each objective.	7		
Total for Ability to Analyze and Interpret experimental Data	80		
Percentage for this Performance Criteria			
TOTAL FOR THIS LAB			

End of Semester Course Assessment Report

This summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department. **You cannot use any number of your choice**
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

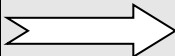
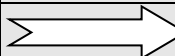
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
MCEG 3101-P01P03 MEASUREMENT AND INSTRUMENTATION LABORATORY
SPRING 2022 SEMESTER

Report Prepared by: Dr. Chang Duan

Report Date: May 20 2022

Semester	Analysis is Type	Number of Students	Sub-Outcome 6.2 Ability to conduct experiments				Sub-Outcome 6.3, 6.4 Ability to analyze and interpret experiment data, and use engineering judgment to draw conclusions				Outcome 6 Ability to conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions			
			Expected Average	Expected Percent of students at or above average	Class Average	% Students Above Expected Average	Expected Average	Expected Percent of students at or above average	Class Average	% Students Above Expected Average	Expected Average	Expected Percent of students at or above average	Class Average	% Students Above Expected Average
Spring 2022	Direct	12	70	70	79.2	83.3	70	70	85.4	100	70	70	84.1	100
Spring 2021	Direct	17	70	70	95.3	94.1	70	70	85	88.2	70	70	87.1	94.1
Spring 2020	Direct	17	70	70	90.1	88.2	70	70	81.8	88.2	70	70	83.4	88.2
Spring 2019	Direct	14	70	70	83.8	100	70	70	87.2	100	70	70	86.5	100
Implementation Summary			1. Theory of the experiment was introduced one week prior to the experiment 2. Data analysis method was detailed explained and demonstrated one week prior to the experiment 3. Detailed instructions on the proper use of the instruments were incorporated in the handouts and discussed in class before starting the experiment				1. Students were asked to compile templates for the pre-laboratory and laboratory report prior to their first report.				As listed in the sub-outcomes			
Perceived Problems			Students tend to forget how to use the instruments very quickly after the experiment is done. Students may feel difficult to correlate the theory with the data acquired in the experiment				1. Most of students do not have any experience in technical writing when entering the class. 2. Students' skills on learning and using Excel and EES vary a lot.				As listed in the sub-outcomes			
Plans for Addressing Problems			Reinforcement is needed for using of instruments. Re-use of instruments in multiple experiments will help Spend more time to explain why the data is acquired and how they are related to the theory. Repeat the key points of theory if necessary				1. More time will be spent in the beginning to prepare the students for the report writing. 2. Demonstrate the software in detail and use sample data as an example				As listed in the sub-outcomes			
Overall Trend over Periods			Class average was above the expected value				Class average was above the expected value				Class average was above the expected value			
Were Expectations Met?	Average≥70%? 70% students avg. ≥70%?		YES				YES				YES			

**Grade Sheet Showing
Student and Class Performance in Outcomes
The computed semester average in each outcome
as stated in the Assessment report are
highlighted in boldface**

**Grade Sheet Showing Student and Class
Performance in Course Outcomes
MCEG 3101-P01P03 Measurement and Instrumentation Laboratory
SPRING 2022 Semester**

	OUTCOME 6.2				OUTCOME 6.3, 6.4				OUTCOME 6			
	Assignment 1	Assignment 2	Average	Percentage	Assignment 1	Assignment 2	Average	Percentage	Assignment 1	Assignment 2	Average	Percentage
	20	20	20	100	80	80	80	100	100	100	100	100
	15	15	15	75	67.5	64	65.8	82.2	82.5	79	80.8	80.8
	15	20	17.5	87.5	61.5	64	62.8	78.4	76.5	84	80.3	80.3
	15	15	15	75	71	56	63.5	79.4	86	71	78.5	78.5
	15	20	17.5	87.5	76	70.5	73.3	91.6	91	90.5	90.8	90.8
	15	15	15	75	76.5	62.5	69.5	86.9	91.5	77.5	84.5	84.5
	15	20	17.5	87.5	71	72	71.5	89.4	86	92	89.0	89.0
	19	15	17	85	77.5	68	72.8	90.9	96.5	83	89.8	89.8
	15	15	15	75	75.5	63.5	69.5	86.9	90.5	78.5	84.5	84.5
	20	20	20	100	80	79	79.5	99.4	100	99	99.5	99.5
	15	15	15	75	54.5	60	57.3	71.6	69.5	75	72.3	72.3
	15	12	13.5	67.5	68.5	69.5	69.0	86.3	83.5	81.5	82.5	82.5
	12	12	12	60	65.5	65	65.3	81.6	77.5	77	77.3	77.3
AVERAGE	15.5	16.2	15.8	79.2	70.4	66.2	68.3	85.4	85.9	82.3	84.1	84.1
SDEV	2.0	2.9	2.1	10.3	7.1	5.8	5.6	7.0	8.3	7.6	7.0	7.0
EXPECTED AVERAGE				70				70				70
STUDENTS ABOVE EXPECTED AVERAGE (%)				83.3				100.0				100.0

**OUTCOME SPECIFIC ASSIGNMENTS
USED TO ASSESS OUTCOMES**

**(Provide at least two assignments used to specifically
measure each outcome and justify the suitability of the
assignments for the outcome being measured)**

ASSIGNMENTS FOR OUTCOME “6.2”, “6.3” and “6.4”

6.2 Ability to conduct experiments

6.3 Ability to analyze and interpret experiment data

6.4 Draw appropriate conclusions and recommendations

**MECHANICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
MEASUREMENT AND INSTRUMENTATION**

LABORATORY SPRING 2022

Instructor: Dr. Chang Duan

Title of Assignment

ASSIGNMENT 1

**Experiment #3 CALIBRATION OF PRESSURE GAUGE AND
PRESSURE TRANSDUCERS USING THE DEAD WEIGHT
TESTER**

Outcome 6

6.2 Ability to conduct experiments
6.3 Ability to analyze and interpret experiment data
6.4 Draw appropriate conclusions and recommendations

Brief Description of the suitability of this assignment for the outcome

This laboratory report assesses ability to conduct experiments, ability to analyze and interpret experiment data and draw appropriate conclusions and recommendations

CALIBRATION OF PRESSURE GAUGE AND PRESSURE TRANSDUCERS USING THE DEAD WEIGHT TESTER

OBJECTIVES:

1. To perform a pressure gauge calibration using a dead weight tester.
2. To perform a pressure transducer calibration using a dead weight tester
3. To use EES to determine the calibration equation using a curve fit.

THEORY: (As presented in class)

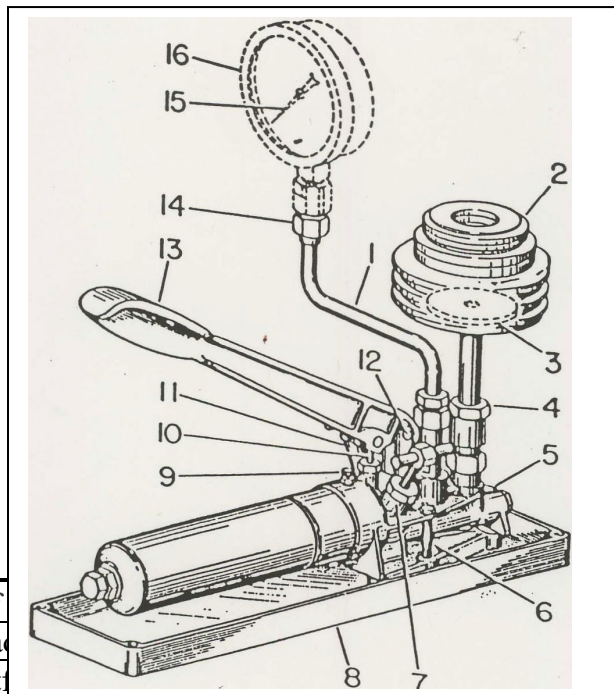
Please summarize the Pascal's pressure law discussed in class here for the theory.

APPARATUS:

Dead weight tester, weights, voltmeter and pressure transducer.

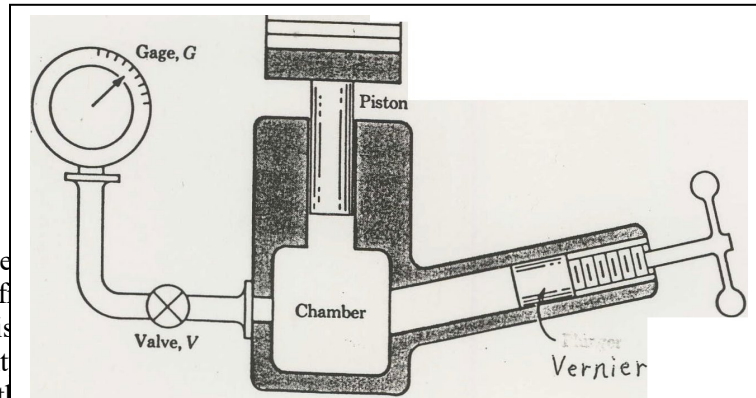
Dead Weight Tester

The dead weight tester is a device used for balancing a fluid pressure with a known weight. It is used for static calibration of pressure gauges or transducer. Its schematic is shown in Figure 1. The chamber and cylinder are filled with a clean oil for pressure generation and transmission. The gauge or transducer to be tested is installed and the piston inserted in the cylinder. The oil is pressurized by a pump. The pressure exerted on the fluid by the piston is transmitted to the gauge or transducer when the valve is opened. This pressure is varied by adding weights to the piston and pumping oil into the cylinder. The accuracy of dead weight tester is limited by two factors:



1	Off		
2	Dea		
3	Plat		
4	Dead weight cylinder	12	Clevis pin
5	Body	13	Handle
6	Bolt	14	Union nut
7	Relief valve	15	Gauge pointer

8	Drip pan	16	Gauge



- (1) The friction between the piston and the cylinder wall is reduced by the viscous film of oil that forms when rotating the piston.
- (2) The uncertainty in the measurement of the force of the piston is reduced by the use of a vernier cylinder. There is some of the effective area between these two which depends on the clearance spacing and the viscosity of the oil. The smaller the clearance, the more closely the effective area will approximate the cross-sectional area of the piston. It can show that percentage error due to clearance varies as:

$$\text{Percent error} \sim \frac{b^{3\sqrt{(\rho P)}}}{\mu DL}$$

Where:

ρ = density of oil

P = pressure on the cylinder

b = clearance spacing $(D_c - D_p)/2$

μ = viscosity of oil

D_c = cylinder diameter

D_p = piston diameter

L = piston length

At high pressure there can be an elastic deformation of the cylinder which increases the clearance spacing and thus increasing the error of the test. There are two kind of pistons used on the dead weight tester for different pressure ranges of gauge or transducer. The cross section areas of pistons are different. The weights of the two pistons are the same.

PROCEDURE:

1. If the 0.5 lb piston is not already inserted in the cylinder, then insert it in the cylinder.
2. Close the valve and pump the oil into the chamber until the platform is raised up. Use the vernier valve to adjust position of the platform.
3. Rotate the platform weight assembly while the measurement is taken. Record both the weight on the platform, the True pressure calculated using $P_{\text{True}} = \text{Weight} / A_{\text{piston}}$, and pressure indicated by the pressure gauge (for the case of pressure gauge calibration) or the volts on the voltmeter (for the case of pressure transducer calibration).
4. Repeat step 3 for each increment of 0.5 lb weight until the highest reading of the pressure gauge or the pressure transducer is reached (or a predetermined value).

Report:

1. Using EES, define the variables in the table headings

2. Compute the average of the two readings of the output voltages and the output pressure on the pressure gauges
3. For Table 2, plot Generated True Pressure Versus the average voltage, and then fit the best straight line through the data points, and then plot the equation on the graph. Note the statistics of the straight line fit.
4. For Table 3, plot Generated True Pressure Versus the output on the pressure gauge, and then fit the best straight line through the data points, and then plot the equation on the graph. Note the statistics of the straight line fit.
5. Complete your report using the standard format for lab reporting.

Table 2 Raw Data for 0-50 PSI Pressure Transducer

$A = 0.1 \text{ in}^2$ Generated Pressure = Weight/A

Weight (lb)	Generated True Pressure (psig)	Output voltage of pressure transducer	
		Loading	Unloading
		Volts	Volts
0	0		
0.5	5		
1.0	10		
1.5	15		
2.0	20		
2.5	25		
3.0	30		
3.5	35		
4.0	40		
4.5	45		
5.0	50		

Table 3 Raw data for 0-250 Pressure Gauge psi

$A = 0.02 \text{ in}^2$ Generated Pressure = Weight/A

Weight (lb)	Generated True	Output on Pressure Gauge
-------------	----------------	--------------------------

	Pressure (psig)	Loading	Unloading
		psi	psi
0	0		
0.5	25		
1.0	50		
1.5	75		
2.0	100		
2.5	125		
3.0	150		
3.5	175		
4.0	200		
4.5	225		
5.0	250		

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



MCEG 3101 MEASUREMENT LABORATORY

Spring 2022 Section P01

LABORATORY REPORT ON

“Calibration of Pressure Gauge and Pressure Transducers using the Dead Weight Testers”

**Conducted on
March 2, 2022**

**Submitted by
O’Neal Perry
On
March 21, 2022**

To

Dr. Chang Duan
Measurement Laboratory Instructor



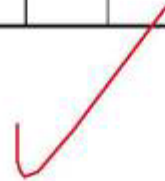
MECHANICAL ENGINEERING DEPARTMENT
MEASUREMENT LABORATORY
LABORATORY GRADING SHEET
SPRING 2022 SECTION P01

Title of Experiment: Calibration of Pressure Gauge and Pressure Transducers using the Dead Weight Tester

Name: O'Neal Perry

Date Lab was Performed: March 2, 2022 Report Due Date: March 21, 2022

<i>Ability to Conduct Experiments</i>	MAX	Your Score	Comments
Ability to demonstrate general lab safety (by your conduct and observations).	3		
Ability to follow the procedure and properly rephrasing the procedure to reflect what you did during the experiment.	7		
Ability to demonstrate knowledge of how equipment function, their limitations, and the uncertainty associated with reading the instruments.	5		
Ability to collect and record the raw data using appropriate units of measurement and identify the dependent and independent variables in the experiment.	5		
Total for Ability to Conduct Experiments	20		
Percentage for this Performance Criteria			
<i>Ability to Analyze and Interpret experimental Data in a Formal Report</i>			
Report format (Ability to properly format and present a technical report)			
Front end of report	4		
General report format	4		
Provides appropriate abstracts for the experimental report	5		
Theory and equations for experimental and theoretical analysis of experimental data especially when requested for	5		
Ability to analyze the data using appropriate software to generate the required parameters using consistent units and significant figures.	22		
Use of statistical analysis as needed including uncertainty analysis	5		
Ability to present the data (raw /derived) in tabular and graphical form to meet the objectives and to aid in interpretation.	14		
Ability to discuss the raw and derived data/graphs and assess the validity of the results in relation to the underlying theory and expected trends.	14		
Ability to draw appropriate and reasonable conclusions in relations to each of the experimental objectives. One conclusion statement for each objective.	7		
Total for Ability to Analyze and Interpret experimental Data	80		
Percentage for this Performance Criteria			
TOTAL FOR THIS LAB			



Letter of Transmittal

O'Neal Perry
Mechanical Engineering Student
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Spring, Texas 77386
Cell: 832-609-6987
E-mail: operry@pvamu.edu

Dr. Chang Duan
Measurement Laboratory Instructor
Prairie View A&M University
C.L. Wilson Engineering Building
Room 105H

March 21, 2022

Dear Dr. Duan:

The following pages are a detailed report for Lab 3 of MCEG 3011 Measurement Laboratory, "Calibration of Pressure Gauge and Pressure Transducers using the Dead Weight Tester". This report discusses the use of a pressure gauge, pressure transducer, and dead weight tester for detailed measurements as well as the use of EES to create parametric tables and plots for the data. The lab was performed on March 2, 2022 and was submitted on March 21, 2022.

If you have any questions or concerns, please call, or email me at any time.

Sincerely,

O'Neal Perry
Enclosure: Lab Report



ABSTRACT

1. The purpose of the experiment

Using a dead weight tester to perform a pressure calibration and gauge calibration. In addition, finding the calibration equation using EES.

2. The brief description of method used

A dead weight tester was used to calculate most of the values for the experiment. The equation weight/area was used to calculate the generated true pressure for the pressure transducer and pressure gauge. EES was used to calculate more equations that were used to create parametric tables and plots.

3. The significant results of the tests

The area of the pressure transducer was 0.1 in^2 , which led to the GTP being ten times greater than the respective weight. For the pressure gauge, the area was 0.02 in^2 , creating a 50-to-1 ratio between the GTP and the weight. There's a near 1-to-1 ratio between the GTP, loading pressure, and unloading pressure.

4. The major conclusions drawn from the results.

For both the pressure transducer and pressure gauge, the loading/unloading voltage and pressure respectively are highly similar for each corresponding weight. GTP for both systems provide a clear numerical relation to the rest of the data. Overall, the data shows that the systems experienced a steady and consistent increase in all areas. More specifically, it can be concluded that the loading and unloading pressures for the pressure gauge are in fact the true pressure for the system.

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CHAPTER 1 ABILITY TO CONDUCT EXPERIMENTS

1.1 Objectives of the Experiment

1. To perform a pressure gauge calibration using a dead weight tester.
2. To perform a pressure transducer calibration using a dead weight tester
3. To use EES to determine the calibration equation using a curve fit.

1.2 Theory Associated with Experiment

The equation for Pascal's Law is $P = F/A$. To put that in words, the pressure in a fluid is equal at all points. To ensure the pressures are constant, the forces and areas need to differ from point to point. Pascal's Law is very vital in creating fully functional engineering systems.

1.3 Apparatus and Uncertainty in Reading Instruments

Dead weight tester, weights, voltmeter, and pressure transducer.

Dead Weight Tester

The dead weight tester is a device used for balancing a fluid pressure with a known weight. It is used for static calibration of pressure gauges or transducer. Its schematic is shown in Figure 1. The chamber and cylinder are filled with a clean oil for pressure generation and transmission. The gauge or transducer to be tested is installed and the piston inserted in the cylinder. The oil is pressurized by a pump. The pressure exerted on the fluid by the piston is transmitted to the gauge or transducer. This pressure is varied by adding weights to the piston and pumping oil into the cylinder. The accuracy of dead weight tester is limited by two factors:

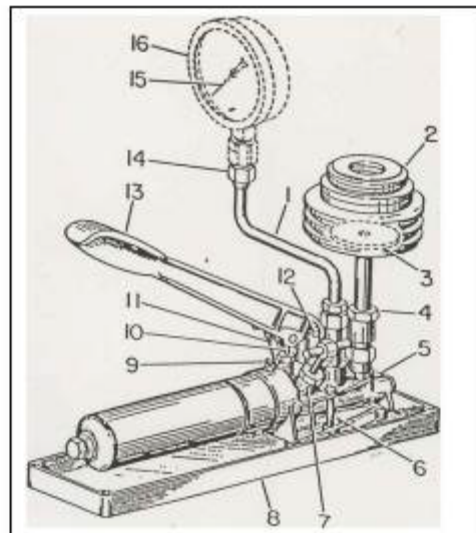


Figure 1.1 The Dead Weight Tester

Table 1.1 Parts of the Deadweight Tester

1	Offset Pipe	9	Air vent
2	Dead weight	10	Piston assembly
3	Platform	11	Vernier valve
4	Dead weight cylinder	12	Clevis pin
5	Body	13	Handle
6	Bolt	14	Union nut
7	Relief valve	15	Gauge pointer
8	Drip pan	16	Gauge

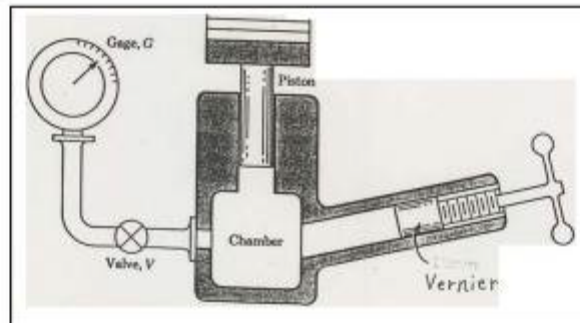


Figure 1.2 Internal sketch of the dead weight tester.

- (1) The friction between the cylinder and the piston
The viscous friction between the piston and the cylinder in the axial direction is reduced by rotating the piston-weight assembly while the measurement is taken.
- (2) The uncertainty in the area of the piston
The force of the weight acts not all at the area of the piston or the area of the cylinder. There is some of the effective area between these two which depends on the clearance spacing and the viscosity of the oil. The smaller the clearance, the more closely the effective area will approximate the cross-sectional area of the piston. It can show that percentage error due to clearance varies as:

$$\text{Percent error} = \frac{b^3 \sqrt{\rho P}}{\mu D L}$$

Where:

ρ = density of oil

P = pressure on the cylinder

b = clearance spacing $(D_c - D_p)/2$

μ = viscosity of oil

D_c = cylinder diameter

D_p = piston diameter

L = piston length

At high pressure there can be an elastic deformation of the cylinder which increases the clearance spacing and thus increasing the error of the test. There are two kinds of pistons used on the dead weight tester for different pressure ranges of gauge or transducer. The cross-section areas of pistons are different. The weights of the two pistons are the same.

1.4 Experimental Safety

Make sure there are no oil leaks before beginning and throughout the experiment. Do not increase the pressure in a reckless manner. Be very careful if any of the objects need to be moved.

1.5 Experimental Procedure

1. Inserted the 0.5 lb piston in the cylinder.
2. Closed the valve and pumped the oil into the chamber until the platform raised up. Used the vernier valve to adjust position of the platform.
3. Rotated the platform weight assembly while the measurement was taken. Recorded both the weight on the platform, the True pressure calculated using $P_{\text{True}} = \text{Weight} / A_{\text{piston}}$, and pressure indicated by the pressure gauge (for the case of pressure gauge calibration) or the volts on the multimeter (for the case of pressure transducer calibration).
4. Repeated step 3 for each increment of 0.5 lb weight until the highest reading of the pressure gauge or the pressure transducer is reached (or a predetermined value).

1.6 Presentation of Raw Experimental Data

Table 1.2 Raw Data for 0-50 PSI Pressure Transducer

$A = 0.1 \text{ in}^2$, Generated Pressure = Weight/A

Weight (lb)	Generated True Pressure (psig)	Output voltage of pressure transducer	
		volts (loading)	volts (unloading)
0	0	1.45	1.42
0.5	5	1.9	1.9
1	10	2.42	2.43
1.5	15	2.92	2.92
2	20	3.43	3.43
2.5	25	3.95	3.93
3	30	4.42	4.43
3.5	35	4.92	4.92
4	40	5.45	5.42
4.5	45	5.95	5.93
5	50	6.42	6.42

Table 1.3 Raw data for 0-250 Pressure Gauge

$A = 0.02 \text{ in}^2$, Generated Pressure = Weight/ A

Weight (lb)	Generated True Pressure (psig)	Output on Pressure Gauge	
		psig (loading)	psig (unloading)
0	0	0	0
0.5	25	25	25
1	50	50	50
1.5	75	75	75
2	100	100	99
2.5	125	125	125
3	150	150	150
3.5	175	174	175
4	200	200	200
4.5	225	225	225
5	250	249.9	249



CHAPTER 2

ABILITY TO ANALYZE EXPERIMENTAL DATA

2.1 Detailed Sample Analysis

$W = 0.5$
 $A1 = 0.1$
 $GTP_{pt} = W/A1 = 5$
 $V1 = 1.9$
 $V2 = 1.9$
 $V = (V1+V2)/2 = 1.9$
 $A2 = 0.02$
 $GTP_{pg} = W/A2 = 25$
 $P1 = 25$
 $P2 = 25$
 $P = (P1+P2)/2 = 25$



2.2 Detailed Computer Analysis of All Data

```

W = 0.5
V1 = 1.9
V2 = 1.9

A1 = 0.1
A2 = 0.02

{V = average(V1,V2)}

GTP_pt = W/A1

GTP_pg = W/A2

{P1 = 25
P2 = 25}

P = average(P1,P2)
    
```



Table 2.1 Equations Window

Unit Settings: SI C kPa kJ mass deg

A1 = 0.1	A2 = 0.02	GTP _{pg} = 25	GTP _{pt} = 5	P = 25	P1 = 25	P2 = 25	V = 1.9	V1 = 1.9	V2 = 1.9	W = 0.5
----------	-----------	------------------------	-----------------------	--------	---------	---------	---------	----------	----------	---------

No unit problems were detected.
 Compilation time = 45 ms Calculation time = 18 ms

Table 2.2 Solutions Window

CHAPTER 2

ABILITY TO ANALYZE EXPERIMENTAL DATA

2.1 Detailed Sample Analysis

$W = 0.5$
 $A1 = 0.1$
 $GTP_{pt} = W/A1 = 5$
 $V1 = 1.9$
 $V2 = 1.9$
 $V = (V1+V2)/2 = 1.9$
 $A2 = 0.02$
 $GTP_{pg} = W/A2 = 25$
 $P1 = 25$
 $P2 = 25$
 $P = (P1+P2)/2 = 25$



2.2 Detailed Computer Analysis of All Data

```

W = 0.5
V1 = 1.9
V2 = 1.9

A1 = 0.1
A2 = 0.02

{V = average(V1,V2)}

GTP_pt = W/A1

GTP_pg = W/A2

{P1 = 25
P2 = 25}

P = average(P1,P2)
    
```



Table 2.1 Equations Window

Unit Settings: SI C kPa kJ mass deg

A1 = 0.1	A2 = 0.02	GTP _{pg} = 25	GTP _{pt} = 5	P = 25	P1 = 25	P2 = 25	V = 1.9	V1 = 1.9	V2 = 1.9	W = 0.5
----------	-----------	------------------------	-----------------------	--------	---------	---------	---------	----------	----------	---------

No unit problems were detected.
 Compilation time = 45 ms Calculation time = 18 ms

Table 2.2 Solutions Window

2.3 Presentation of Tables of Derived Results

Table 1- Pressure Transducer		Table 2- Pressure Gauge			
1.11	GTP _{pt}	V1	V2	W	V
Run 1	0	1.45	1.42	0	1.435
Run 2	5	1.9	1.9	0.5	1.9
Run 3	10	2.42	2.43	1	2.425
Run 4	15	2.92	2.92	1.5	2.92
Run 5	20	3.43	3.43	2	3.43
Run 6	25	3.95	3.93	2.5	3.94
Run 7	30	4.42	4.43	3	4.425
Run 8	35	4.92	4.92	3.5	4.92
Run 9	40	5.45	5.42	4	5.435
Run 10	45	5.95	5.93	4.5	5.94
Run 11	50	6.42	6.42	5	6.42

Table 2.3 Pressure Transducer Parametric Table

Table 1- Pressure Transducer		Table 2- Pressure Gauge			
1.11	GTP _{pg}	P	P1	P2	W
Run 1	3.009E-36	0	0	0	0
Run 2	25	25	25	25	0.5
Run 3	50	50	50	50	1
Run 4	75	75	75	75	1.5
Run 5	100	99.5	100	99	2
Run 6	125	125	125	125	2.5
Run 7	150	150	150	150	3
Run 8	175	174.5	174	175	3.5
Run 9	200	200	200	200	4
Run 10	225	225	225	225	4.5
Run 11	250	249.5	249.9	249	5

Table 2.4 Pressure Gauge Parametric Table

CHAPTER 3

ABILITY TO INTERPRET EXPERIMENTAL DATA

3.1 Presentation of Graphs/Figures, Discussion and Interpretation of Results Presented by each Graph/Figure and Answers to Posed Problems if any.

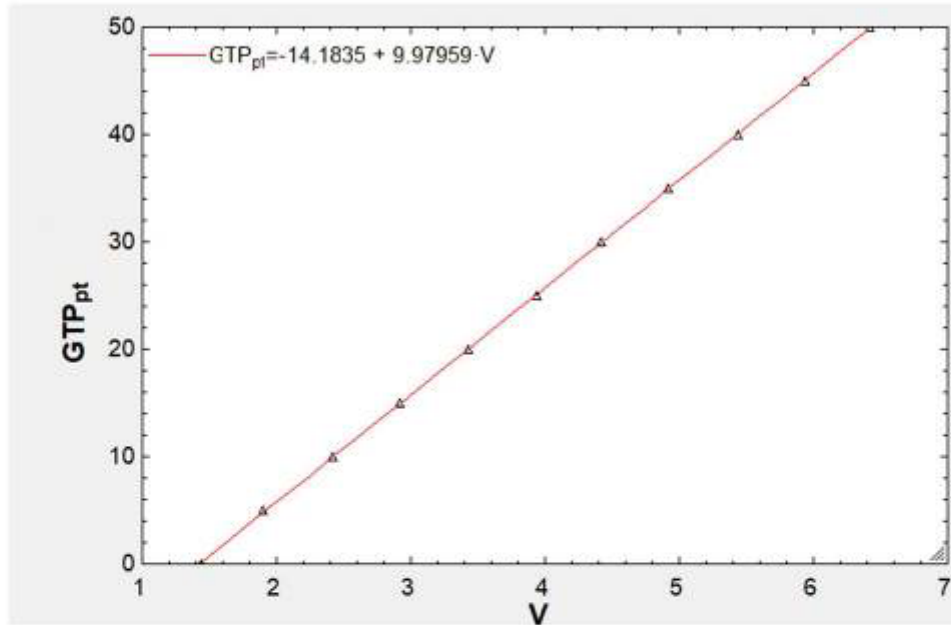


Figure 3.1 Plot for the GTP of the Pressure Transducer

Figure 3.1 displays the general true pressure of the pressure transducer on the y axis. The average voltage is displayed on the x axis. Each triangle represents one of the eleven data points on the plot. The red line is the line of best fit connecting the data points. In the top left corner, the equation for the line is displayed. Overall, the equation represents that the GTP_{pt} is function of the average voltage of the system.

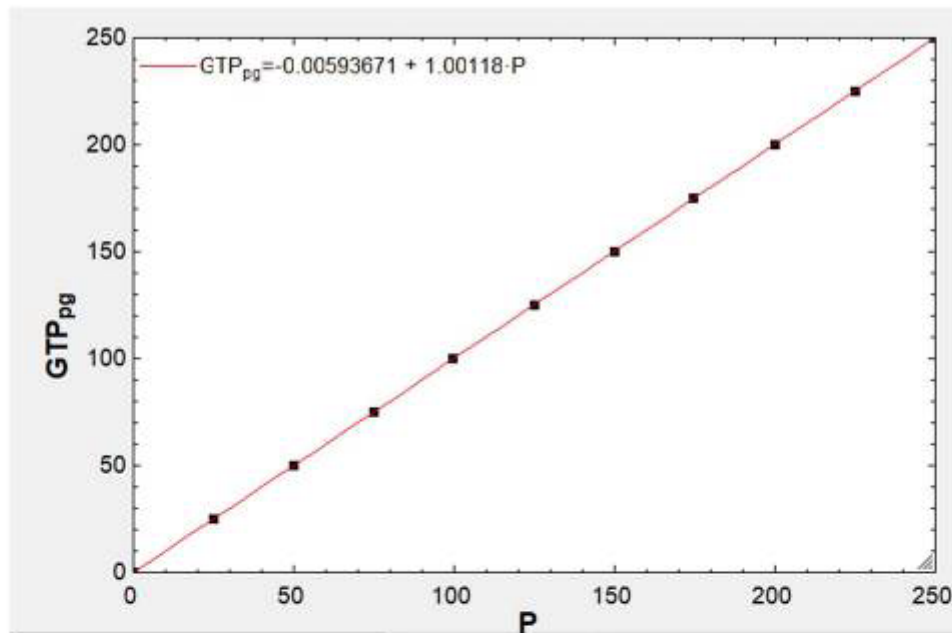


Figure 3.2 Plot for the GTP of the Pressure Gauge

Figure 3.2 plots the general true pressure of the pressure gauge on the y axis versus the average pressure on the x axis. Like the previous plot, there are eleven data points. On both axes, the data spans from zero to two-hundred fifty. The plot and equation show that it's nearly a one-to-one ratio between the two variables.

3.2 Conclusions Based on each Objective and the Results

The GTP_{pg} was calculated for each half-pound increment in weight up to 5 pounds using a dead weight tester. The GTP increases by about 25 psi for each half-pound increase in weight. The pressure values were typically identical, creating a nearly one-to-one ratio for the plot. This leads one to conclude that the loading and unloading pressures are in fact the true pressures.

The GTP_{pt} was calculated for each half-pound increment in weight up to 5 pounds using a dead weight tester. There's a consistent increase of 5 psi for every half pound increase in weight. However, since the value for the area is constant, one can conclude that the GTP is equal to ten times the value of weight.

Using EES, the GTP for the pressure transducer was plotted against the average voltage to determine a linear equation to create a relationship between the two variables. Using the 11 data points for each, the equation was determined to be $GTP_{pt} = -14.1835 + 9.97959V$. This leads to the conclusion that any GTP value is equal to nearly 10 times a voltage minus 14. For the pressure gauge, the GTP was plotted against the average pressures. Based on the equation, one can conclude that the GTP and average pressure values are almost always going to be identical.

3.3 Recommendations

Be sure to understand and interpret the equations from the GTP plots.

Use the right equation and areas to calculate the generated true pressures.

REFERENCES

No references

Microsoft Word
Engineering Equation Solver

APPENDICES

**MECHANICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
MEASUREMENT AND INSTRUMENTATION
LABORATORY SPRING 2022
Instructor: Dr. Chang Duan**

Title of Assignment

ASSIGNMENT 2
**Experiment #4 Statistical Analysis of Experimental Data – Local
Gravitational Acceleration Determination by a Simple Pendulum**

Outcome 6

6.2 Ability to conduct experiments
6.3 Ability to analyze and interpret experiment data
6.4 Draw appropriate conclusions and recommendations

Brief Description of the suitability of this assignment for the outcome

This laboratory report assesses ability to conduct experiments, ability to analyze and interpret experiment data and draw appropriate conclusions and recommendations

STATISTICAL ANALYSIS OF EXPERIMENTAL DATA – LOCAL GRAVITATIONAL ACCELERATION DETERMINATION BY A SIMPLE PENDULUM

Objective:

1. To determine the gravitational acceleration by a simple pendulum
(<https://www.youtube.com/watch?v=z6ZdhP167RY>)
2. To use EES for statistical analysis of experimental data and for computing the uncertainty in the computed variables
3. To present the computed physical quantity from measured data in the form of

$$g = g_m \pm \Delta g$$

Theory:

1. Error Computation

Errors or uncertainty involved in a result due to the uncertainties of the parameters involved in computations of measured values can be best obtained by using the Kline and McClintock formula also known as the Root-Sum-Square law. The formula is given as follows:

$$U_R = \left[\left(\frac{\partial R}{\partial X_1} U_{X_1} \right)^2 + \left(\frac{\partial R}{\partial X_2} U_{X_2} \right)^2 + \left(\frac{\partial R}{\partial X_3} U_{X_3} \right)^2 + \dots + \left(\frac{\partial R}{\partial X_N} U_{X_N} \right)^2 \right]^{\frac{1}{2}} \quad (1)$$

Where,

R	=	the result
U_R	=	uncertainty in the result
X_i	=	parameters involved in computing the result
U_{X_i}	=	uncertainty in the parameters X_i

Experiment

For a simple pendulum with small angular oscillation, neglecting friction, the frequency of oscillation f is given by

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{L}} \quad (9)$$

Where

g	– local gravitational acceleration, m/s^2
L	– length of the string (pendulum length), m
f	– frequency of oscillation, cycles/s

if both side of equation (9) is squared, we get

$$f^2 = \frac{g}{4\pi^2} \frac{1}{L} \quad (10)$$

A graph of f^2 versus $1/L$ will be a straight line with a slope, S , given by

$$S = \frac{g}{4\pi^2} \quad (11)$$

from which g can be computed.

Statistical Analysis

The Mean: The mean x_m , of a set of n data in which each data is represented by x_i ($i=1$ to n) is given by

$$x_m = \frac{1}{n} \sum_{i=1}^n x_i \quad (12)$$

The Deviation: The deviation d_i of a set of n data in which each data is represented by x_i ($i=1$ to n) is given by

$$d_i = |x_i - x_m| \quad (13)$$

Note that the average of the deviations of all the data is zero since the sum of the deviation is zero.

The Mean Deviation: The average of the absolute values of the deviations is however not zero, and is given by

$$\left| \bar{d}_i \right| = \frac{1}{n} \sum |x_i - x_m| \quad (14)$$

The Standard Deviation: The standard deviation is also known as the root mean square deviation. It is one of the most important statistical parameters that is used to ascertain the accuracy as well as the confidence one will have in the value of the measured data. The standard deviation for a very large set of data is given by

$$\sigma = \left[\frac{1}{n} \sum_{i=1}^n (x_i - x_m)^2 \right]^{1/2} \quad (15)$$

When the number of data is not large (greater than 20 for example), the sample standard deviation is given by

$$\sigma = \left[\frac{\sum (x_i - x_m)^2}{n-1} \right]^{1/2} \quad (16)$$

Apparatus:

String, weight, straight rule, stop watch

Procedure:

Note: Each group perform the experiment at one nominal pendulum string length, L_{Nominal} . Each member in the group will then measure the actual pendulum length and then record one set of data.

1. Set the pendulum length to the approximate nominal length prescribed for the group
2. Measure the actual pendulum length in (cm).
3. Swing the pendulum at a small angle from the vertical and record the time required for 10 cycles of oscillations. Note that the count should start from zero (0) at the time the stop watch is started.
4. Record the data on the raw data sheet.

Laboratory Report:

1. Set your Units to SI in EES

- For each nominal length, input the actual lengths, L_1 , L_2 , L_3 , L_4 and L_5 in your EES program and use the average function to calculate the average length, L .
- For each nominal length, input the times for 10 oscillations, T_1 , T_2 , T_3 , T_4 and T_5 in your EES program and use the average function to calculate the average time, T for 10 oscillations
- Calculate the frequency, f , as $f=N/T$ where $N= 10$ oscillations.
- Set $Y=f^2$ and $X=1/L$
- For the data for the pendulum lengths measured, compute the sum of absolute deviations, d_L , the mean deviation, d_{mL} , and the standard deviation σ_L for the data at each nominal pendulum length.
- For the data for the time, T , for 10 oscillations measured, compute the sum of absolute deviations, d_T , the mean deviation, d_{mT} , and the standard deviation σ_T for the data at each nominal pendulum length.
- Run your program to ensure it works properly
- Create a Table in EES with the columns L_1 , L_2 , L_3 , L_4 , L_5 , T_1 , T_2 , T_3 , T_4 , T_5 , L , T , f , X , Y , d_L , d_{mL} , σ_L , d_T , d_{mT} , and σ_T ,
- Transfer the raw data into the EES table you have created.
- Use the Solve table command to solve the table after commenting out the raw data variables in the program.
- Plot Y versus X . This should come out as a straight line
- Use EES to fit the best straight line through the points and note the statistics for the fit.
- Plot the equation of the straight line on the plot and indicate the slope
- Input the value of the slope, S , in your EES Equation and use Equation (3) to compute the value of g .
- Using the maximum values of the standard deviations as the uncertainty in the experimental data, use EES to compute the uncertainty in the slope and in the computed value of g .

Formal Laboratory Report

- Present the information in a well written standard laboratory report following the detailed report format provided to you and discussed in class.
- Completely discuss and interpret your results including all graphs and computed results as required.

Table 1 Sample Experimental Data

Nominal Length	Length of Pendulum (cm)		Time for N=10 Oscillations (sec.)	
85cm	L1	81.1	T1	17.94
	L2	82.0	T2	19.10
	L3	82.0	T3	17.93
	L4	82.1	T4	17.89
	L5	82.0	T5	19.40
75cm	L1	74.5	T1	17.34
	L2	75.0	T2	17.35
	L3	74.9	T3	17.39
	L4	74.8	T4	17.45
	L5	75.1	T5	17.13

65cm	L1	66.4	T1	16.24
	L2	66.5	T2	16.25
	L3	65.1	T3	16.47
	L4	64.0	T4	16.23
	L5	65.3	T5	16.26
55cm	L1	55.0	T1	14.25
	L2	55.0	T2	15.24
	L3	55.0	T3	14.62
	L4	55.5	T4	15.19
	L5	55.0	T5	16.00
45cm	L1	45.2	T1	13.89
	L2	45.0	T2	13.83
	L3	45.0	T3	13.96
	L4	45.0	T4	13.60
	L5	45.2	T5	13.63
35cm	L1	34.5	T1	11.65
	L2	34.5	T2	11.71
	L3	34.5	T3	11.66
	L4	34.5	T4	11.07
	L5	34.5	T5	11.60

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



MCEG 3101 MEASUREMENT LABORATORY

Spring 2022 Section P03

LABORATORY REPORT ON

**“Local Gravitational Acceleration Determination by a Simple
Pendulum”**

**Conducted on
March 21, 2022**

**Submitted by
Caleb Combs**

**On
April 4, 2022**

To

Dr. Chang Duan
Measurement Laboratory Instructor

**MECHANICAL ENGINEERING DEPARTMENT
MEASUREMENT LABORATORY
LABORATORY GRADING SHEET
SPRING 2022 SECTION P03**

Title of Experiment: _____

Name: _____

Date Lab was Performed: _____ **Report Due Date:** _____

<i>Ability to Conduct Experiments</i>	MAX	Your Score	Comments
Ability to demonstrate general lab safety (by your conduct and observations).	3		
Ability to follow the procedure and properly rephrasing the procedure to reflect what you did during the experiment.	7		
Ability to demonstrate knowledge of how equipment function, their limitations, and the uncertainty associated with reading the instruments.	5		
Ability to collect and record the raw data using appropriate units of measurement and identify the dependent and independent variables in the experiment.	5		
Total for Ability to Conduct Experiments	20		
Percentage for this Performance Criteria			
<i>Ability to Analyze and Interpret experimental Data in a Formal Report</i>			
Report format (Ability to properly format and present a technical report)			
Front end of report	4		
General report format	4		
Provides appropriate abstracts for the experimental report	5		
Theory and equations for experimental and theoretical analysis of experimental data especially when requested for	5		
Ability to analyze the data using appropriate software to generate the required parameters using consistent units and significant figures.	22		
Use of statistical analysis as needed including uncertainty analysis	5		
Ability to present the data (raw /derived) in tabular and graphical form to meet the objectives and to aid in interpretation.	14		
Ability to discuss the raw and derived data/graphs and assess the validity of the results in relation to the underlying theory and expected trends.	14		
Ability to draw appropriate and reasonable conclusions in relations to each of the experimental objectives. One conclusion statement for each objective.	7		
Total for Ability to Analyze and Interpret experimental Data	80		
Percentage for this Performance Criteria			
TOTAL FOR THIS LAB			



Letter of Transmittal

Caleb Combs
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Dr. Chang Duan
Measurement Laboratory Instructor
Prairie View A&M University
C.L. Wilson Engineering Building
Room 105H

April 4, 2022

Dear Dr. Duan:

The following pages are a detailed report for lab 4 of MCEG 3011 Measurement Laboratory, "Local Gravitational Acceleration Determination by a Simple Pendulum". This report addresses the determination of the gravitation acceleration by a simple pendulum, statistical analysis of experimental data, and uncertainty in the computed variables. The lab was performed on March 21, 2022. This lab was submitted on April 4, 2022.

If you have any questions or concerns, please call or email me at any time.

Sincerely,

Caleb Combs
Enclosure: Lab Report



ABSTRACT

The purpose of the experiment

The purpose of this experiment was to determine the gravitational acceleration by a simple pendulum. It was also to gain experience using EES for statistical analysis of experimental data and for computing the uncertainty in the computed variables. The goal of this experiment was also to present the computed physical quantity from measured data in the form of $g = g_m \pm \Delta g$.

The brief description of method used

The method used for this experiment began with setting the pendulum to the approximate nominal length prescribed for the group. Next, each group member measured the actual pendulum length in centimeters. The pendulum was then swung at a small angle from the vertical and the time required for 10 cycles of oscillations was recorded by each group member. This procedure was repeated for the remaining five pendulum nominal lengths.

The significant results of the tests

A significant result of this experiment is that the relationship between X and Y for the pendulum is very close to being linear. The relationship between X and Y is close to being linear because the data points for the X and Y plot are all close to the curve fitting line. Another significant result is that there is some uncertainty in the computed gravitational constant.

The major conclusions drawn from the results

It can be concluded that the slope of the curve fitting line for the X-Y plot can be used to make an acceptable approximation of the gravitational constant. However, it can also be concluded that uncertainty and inaccuracy are present in the computed gravitation constant due to the assumptions made that the pendulum is swung at a small angle and is not affected by damping.



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CHAPTER 1

ABILITY TO CONDUCT EXPERIMENTS

1.1 Objectives of the Experiment

1. To determine the gravitational acceleration by a simple pendulum
2. To use EES for statistical analysis of experimental data and for computing the uncertainty in the computed variables
3. To present the computed physical quantity from measured data in the form of $g = gm \pm \Delta g$

1.2 Theory Associated with Experiment

1. Error Computation

Errors or uncertainty involved in a result due to the uncertainties of the parameters involved in computations of measured values can be best obtained by using the Kline and McClintock formula also known as the Root-Sum-Square law. The formula is given as follows:

$$U_R = \left[\left(\frac{\partial R}{\partial X_1} U_{X_1} \right)^2 + \left(\frac{\partial R}{\partial X_2} U_{X_2} \right)^2 + \left(\frac{\partial R}{\partial X_3} U_{X_3} \right)^2 + \dots + \left(\frac{\partial R}{\partial X_N} U_{X_N} \right)^2 \right]^{\frac{1}{2}} \quad (1)$$

Where, R = the result

U_R = uncertainty in the result

X_i = parameters involved in computing the result

U_{X_i} = uncertainty in the parameters X_i

Example 4.1

A pressurized air tank is stored in a laboratory where the nominal ambient temperature is 27 °C. The air temperature is measured using a sensor with an uncertainty of 1 °C and the uncertainty in pressure measurement is 1%. Evaluate the uncertainty in determining the air density using the equation of state for an ideal gas.

The data reduction equation is

$$\rho = \frac{p}{RT} \quad (2)$$

The uncertainty expression becomes

$$U_\rho = \left[\left(\frac{\partial \rho}{\partial p} U_p \right)^2 + \left(\frac{\partial \rho}{\partial R} U_R \right)^2 + \left(\frac{\partial \rho}{\partial T} U_T \right)^2 \right]^{\frac{1}{2}} \quad (3)$$

The partial derivatives are

$$\frac{\partial \rho}{\partial p} = \frac{1}{RT} \quad (4)$$

$$\frac{\partial \rho}{\partial R} = -\frac{p}{R^2 T} \quad (5)$$

$$\frac{\partial \rho}{\partial T} = -\frac{p}{RT^2} \quad (6)$$

Substitution of the partial derivatives into (3) gives

$$U_{\rho} = \left[\left(\frac{1}{RT} U_p \right)^2 + \left(\frac{-p}{R^2 T} U_R \right)^2 + \left(\frac{-p}{RT^2} U_T \right)^2 \right]^{\frac{1}{2}} \quad (7)$$

Dividing the uncertainty expression (7) by the data reduction equation (2) gives

$$\frac{U_{\rho}}{\rho} = \left[\left(\frac{U_p}{p} \right)^2 + \left(\frac{U_R}{R} \right)^2 + \left(\frac{U_T}{T} \right)^2 \right]^{\frac{1}{2}} \quad (8)$$

Values for the variables are

$$T = 27^{\circ}\text{C} = 300\text{K}$$

$$U_T = 1^{\circ}\text{C} = 1\text{K}$$

$$\frac{U_p}{p} = 0.01$$

$$U_R = 0.0$$

The uncertainty in R , i.e. U_R is assumed negligible since the gas constant is available in reference sources with a great degree of certainty. Substitution of the numerical values in equation (8) gives the uncertainty in the air density

$$\frac{U_{\rho}}{\rho} = 0.011 = 1.1\%$$

The analysis presented for the above example problem shows the necessary steps in a general uncertainty analysis. 

2. For a simple pendulum with small angular oscillation, neglecting friction, the frequency of oscillation f is given by

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{L}} \quad (1)$$

Where g – local gravitational acceleration, m/s^2

L – length of the string (pendulum length), m

f – frequency of oscillation, cycles/s

if both side of equation 1 is squared, we get

$$f^2 = \frac{g}{4\pi^2} \frac{1}{L} \quad (2)$$

A graph of f^2 versus $1/L$ will be a straight line with a slope, S , given by

$$S = \frac{g}{4\pi^2} \quad (3)$$

from which g can be computed.

Statistical Analysis

The Mean: The mean x_m , of a set of n data in which each data is represented by x_i ($i=1$ to n) is given by

$$x_m = \frac{1}{n} \sum_{i=1}^n x_i \quad (4)$$

The Deviation: The deviation d_i of a set of n data in which each data is represented by x_i ($i=1$ to n) is given by

$$d_i = |x_i - x_m| \quad (5)$$

Note that the average of the deviations of all the data is zero since the sum of the deviation is zero.

The Mean Deviation: The average of the absolute values of the deviations is however not zero, and is given by

$$\bar{d}_i = \frac{1}{n} \sum |x_i - x_m| \quad (6)$$

The Standard Deviation: The standard deviation is also known as the root mean square deviation. It is one of the most important statistical parameters that is used to ascertain the accuracy as well as the confidence one will have in the value of the measured data. The standard deviation for a very large set of data is given by

$$\sigma = \left[\frac{1}{n} \sum_{i=1}^n (x_i - x_m)^2 \right]^{1/2} \quad (7)$$

When the number of data is not large (greater than 20 for example), the sample standard deviation is given by



$$\sigma = \left[\frac{\sum (x_i - x_m)^2}{n-1} \right]^{1/2} \quad (8)$$

1.3 Apparatus and Uncertainty in Reading Instruments

String, weight, straight ruler, stopwatch

1.4 Experimental Safety

No experimental safety concerns were observed.

1.5 Experimental Procedure

To start, the pendulum length was set to the approximate nominal length prescribed for the group. Next, the actual pendulum length was measured in (cm) by each group member. Then, the pendulum was swung at a small angle from the vertical and the time required for 10 cycles of oscillations was recorded by each group member. The count started from zero (0) at the time the stopwatch was started. This procedure was repeated for the remaining five pendulum nominal lengths. All length and time measurements were then put into excel and the lab instructor posted this data on e-courses.



1.6 Presentation of Raw Experimental Data

Table 1.1 shows the raw experimental data for the pendulum.

Norminal Length	Measured Length (cm)		Time (sec)	
85cm	L1:	83.5	T1	18.24
	L2	84	T2	18.36
	L3	84	T3	17.92
	L4	83	T4	17.98
	L5	84	T5	17.26
75cm	L1	75.5	T1	15.05
	L2	74.7	T2	15.26
	L3	75	T3	15.2
	L4	75	T4	15.39
	L5	76	T5	15.45
65cm	L1	63.9	T1	15.46
	L2	64	T2	15.96
	L3	65.5	T3	15.88
	L4	63.7	T4	16.04
	L5	65	T6	14.93
55cm	L1	55.8	T1	14.59
	L2	55.5	T2	14.55
	L3	54.5	T3	14.8
	L4	57	T4	14.43
	L5	55.6	T5	14.83
45cm	L1	45.7	T1	14.15
	L2	45	T2	13.21
	L3	46	T3	13.28
	L4	44.5	T4	13.61
	L5	44.4	T5	12.84
35cm	L1	34.3	T1	11.43
	L2	35	T2	11.32
	L3	34	T3	11.7
	L4	35	T4	11.41
	L5	34.4	T5	11.46

Table 1.1 Raw Experimental Data

Table title should be above the table ✓

CHAPTER 2

ABILITY TO ANALYZE EXPERIMENTAL DATA

2.1 Detailed Sample Analysis

$$L1 = 0.835$$

$$L2 = 0.84$$

$$L3 = 0.84$$

$$L4 = 0.83$$

$$L5 = 0.84$$

$$T1 = 18.24$$

$$T2 = 18.36$$

$$T3 = 17.92$$

$$T4 = 17.98$$

$$T5 = 17.26$$

$$L = (L1 + L2 + L3 + L4 + L5)/5 = 0.837$$

$$T = (T1 + T2 + T3 + T4 + T5)/5 = 17.95$$

$$D_L = |L - L1| + |L - L2| + |L - L3| + |L - L4| + |L - L5| = 0.018$$

$$D_mL = D_L/5 = 0.0036$$

$$\sigma_L = \sqrt{\frac{[(L - L1)^2 + (L - L2)^2 + (L - L3)^2 + (L - L4)^2 + (L - L5)^2]}{4}} = 0.004472$$

$$D_T = |T - T1| + |T - T2| + |T - T3| + |T - T4| + |T - T5| = 1.448$$

$$D_mT = D_T/5 = 0.2896$$

$$\sigma_T = \sqrt{\frac{[(T - T1)^2 + (T - T2)^2 + (T - T3)^2 + (T - T4)^2 + (T - T5)^2]}{4}} = 0.4272$$

$$S = 0.2390977$$

$$g = 9.439$$



2.2 Detailed Computer Analysis of All Data

Table 2.1a shows the first part of the EES parametric table for the pendulum.

1.6	1	d _L	2	d _{mL}	3	d _{mT}	4	d _T	5	L1	6	L2	7	L3	8	L4	9	L5
Run 1		0.018		0.0036		0.2896		1.448		0.835		0.84		0.84		0.83		0.84
Run 2		0.0204		0.00408		0.12		0.6		0.755		0.747		0.75		0.75		0.76
Run 3		0.0332		0.00664		0.3672		1.836		0.639		0.64		0.655		0.637		0.65
Run 4		0.0288		0.00576		0.14		0.7		0.558		0.555		0.545		0.57		0.556
Run 5		0.0292		0.00584		0.3696		1.848		0.457		0.45		0.46		0.445		0.444
Run 6		0.0184		0.00368		0.0944		0.472		0.343		0.35		0.34		0.35		0.344

Table 2.1a EES Pendulum Parametric Table 1

Table 2.1b shows the second part of the EES parametric table for the pendulum.

10	σ _L	11	σ _T	12	T	13	T1	14	T2	15	T3	16	T4	17	T5	18	X	19	Y
	0.004472		0.4272		17.95		18.24		18.36		17.92		17.98		17.26		1.195		0.3103
	0.005128		0.1583		15.27		15.05		15.26		15.2		15.39		15.45		1.329		0.4289
	0.007855		0.4625		15.65		15.46		15.96		15.88		16.04		14.93		1.552		0.4081
	0.008927		0.1706		14.64		14.59		14.55		14.8		14.43		14.83		1.796		0.4666
	0.00712		0.4922		13.42		14.15		13.21		13.28		13.61		12.84		2.216		0.5554
	0.00445		0.1419		11.46		11.43		11.32		11.7		11.41		11.46		2.895		0.7609

Table 2.1b EES Pendulum Parametric Table 2

2.3 Presentation of Tables of Derived Results

Figure 2.1 shows the EES solutions window.

Unit Settings: SI C kPa kJ mass deg
g = 9.439 S = 0.2391
No unit problems were detected.
Compilation time = 47 ms Calculation time = 46 ms

Figure 2.1 EES Solutions Window

Figure 2.2 shows the curve fitting statistics for the pendulum.

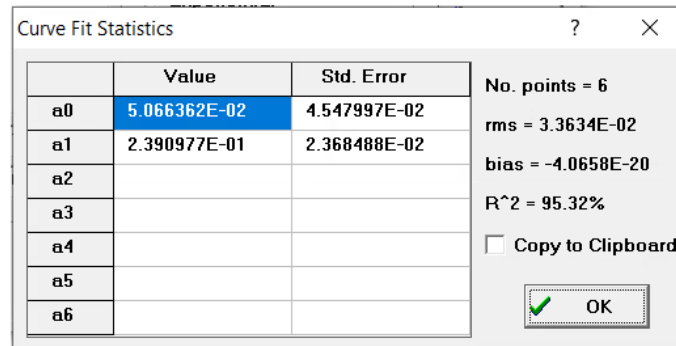


Figure 2.2 Curve Fit Statistics

Figure 2.3 shows the uncertainty results for the pendulum.

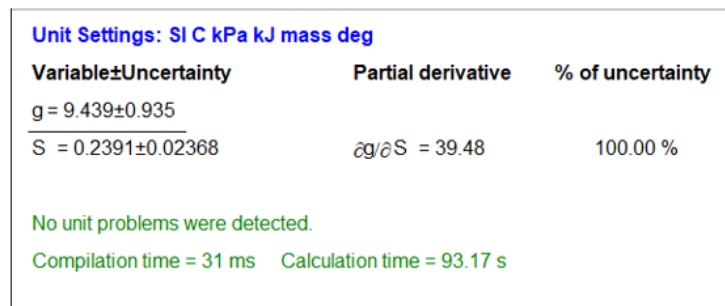


Figure 2.3 Uncertainty Results

CHAPTER 3

ABILITY TO INTERPRET EXPERIMENTAL DATA

3.1 Presentation of Graphs/Figures, Discussion and Interpretation of Results Presented by each Graph/Figure and Answers to Posed Problems if any.

Figure 3.1 Shows X-Y plot with the curve fitting equation.

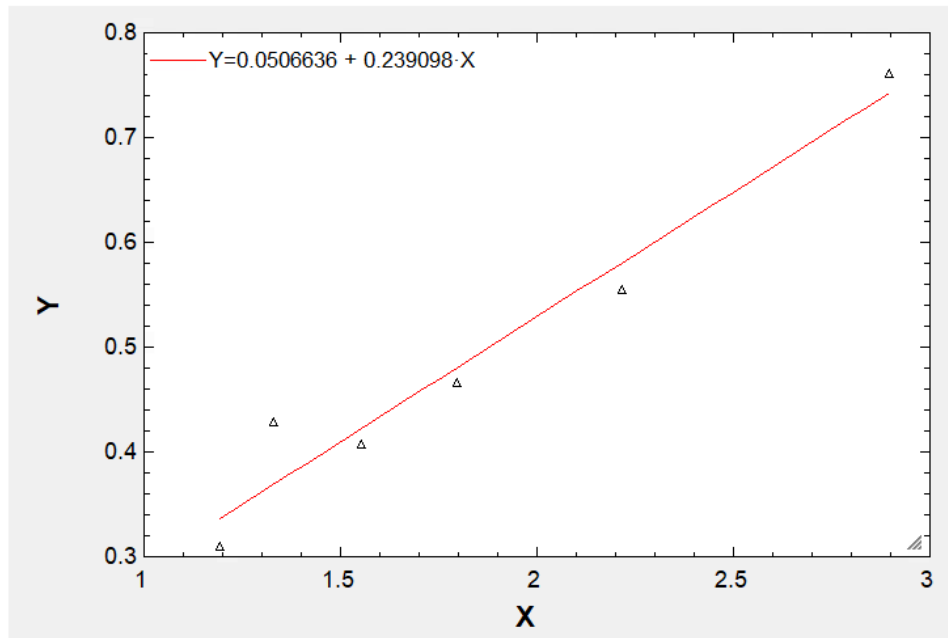


Figure 3.1 X-Y Plot with Curve Fitting Equation

It is evident in the results that the relationship between X and Y for the pendulum is very close to being linear. This means that the slope for the curve fitting line can be utilized to make a good approximation of the gravitational constant.

3.2 Conclusions Based on each Objective and the Results

Since the data points are all very close to the curve fitting line, it can be concluded that the relationship between X and Y is approximately linear. Therefore, it is acceptable to use the slope of the curve fitting line to approximate the gravitational constant.

It can also be concluded the inaccuracy and uncertainty of the approximated gravitational constant is primarily due to the assumptions made for this lab. For instance, it was assumed that the angle of the pendulum at the starting point of its oscillation was very small; in reality, it may have been too large. Also, it was assumed that there were no damping effects; however, damping effects still occurred during the experimentation. Since the calculations made to find the gravitational constant are based on these assumptions, the calculated gravitational constant possesses some uncertainty and inaccuracy.

As for conclusions that can be made based on each objective, it is evident that the gravitational acceleration can be determined using a simple pendulum, but the determined value there will be inaccuracy due to human error and damping effects. Also, EES can be utilized for statistical analysis of experimental data and for computing the uncertainty in the computed variables. Finally, the computed physical quantity from measured data can be represented in the form of $g = g_m \pm \Delta g$.



3.3 Recommendations

No recommendations are needed for this lab.