ME-308L Measurement & Instrumentation Lab

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Experiment 0. Lab Guidelines

0.1 Course Learning Outcomes (CLOs)

The learning outcomes that are expected to be attained by the student at the end of the course are given in Table 0.1-1. The **CLO #3** is applicable only if lab is **Open Ended Lab (OEL)**. The List of **Program Learning Outcomes (PLOs)** of BS program of Mechanical Engineering Department are given in **Appendix A**.

Table 0.1-1: Course learning outcomes of ME-207L thermodynamics Lab

Sr. #	CLO Statement	Domain	Level	PLO
1	**DISPLAY** basic proficiency in operation of the apparatus and **PERFORM** the experiment to determine the solution of the engineering problems related to the subject.	Psychomotor	4	4
2	**Communicate** the learned concepts using different media i.e., verbal and written.	Affective	2	10
3	**Manifest** the professional responsibilities and norms of engineering practice.	Affective	3	8

The **Detail of Domains** and their Levels mentioned against each course learning outcome, is mentioned in **Appendix B**. The mapping of course learning outcomes with the program learning outcomes is given as in Table 0.1-2. The performance of you in course will be measured based on above learning outcomes using **Rubrics** mentioned in **Appendix C**.

Table 0.1-2: Relation of CLOs of thermodynamics Lab with PLOs

PLO #	PLO Statement	CLO1	CLO2	CLO3
PLO-1	**Engineering Knowledge**			
PLO-2	**Problem Analysis**			
PLO-3	**Design/Development of Solution**			
PLO-4	**Investigation**	✓		
PLO-5	**Modern Tool Usage**			
PLO-6	**The Engineer and Society**			
PLO-7	**Environment and Stability**			

PLO-8	**Ethics**			✓
PLO-9	**Individual and Team Work**			
PLO-10	**Communication**		✓	
PLO-11	**Project Management**			
PLO-12	**Life Long Learning**			

0.2 Guidelines for Lab Report

Lab report must be submitted/checked within **7 days effectively** after the experiment is conducted. Lab report may not be accepted/checked after due date and lab report marks may be deducted.

0.2.1 Content

The content contain guidelines about the report structure, the constituent headings and content to be written under the headings.

0.2.1.1 Cover Page

The cover page should contain the followings

- Lab Name
- Experiment Name
- Students' Name
- Group #
- Lab Instructor Name
- Date on which lab Experiment was conducted (See the Lab schedule for it)
- Submission date of Lab Report

The format and Alignment and arrangement of above mentioned is student's own choice.

0.2.1.2 Abstract

The abstract contains summary lab activity done and contains the following main points.

1. Purpose/ objective(s) of the experiment
2. Main results in the experiment
3. Main results of experiment
4. Main conclusion

The abstract should be of one paragraph with words not more than 200 words.

0.2.1.3 Introduction

This section is meant for describing the worth/importance/significance of your work. As a part of arguments for proving your work a useful one it is logical to briefly point out the similar work already done by others but a detailed literature review is not a part of introduction.

As a part of description of the importance of work you may also justify your choice of problem solution methodology. When there are potentially more than one approaches available for the solution of the same problem; it is logical to opt for the best available choice giving due regard to the resource constraints.

Through introduction of the report you try to convince the reader that your work is really useful. According to a researcher “Introduction is setting up the scene”.

Wherever necessary there may be a separate section of theory but it must not be dragged into introduction.

0.2.1.4 Theory

It is an optional section and is included to appraise the reader the theory of your work. In the lab reports we normally do not recommend to include this section.

0.2.1.5 Procedure

In this section it is recommended to enlist the sequential steps for taking proper data. Wherever applicable a block diagram of the experimental set up is to be included. The diagrams should be properly labeled.

While writing a lab experiment procedure do not adopt the style of instructor. It is generally recommended to use past tense and passive voice. In technical writings the use of “I” and “We” is generally not appreciated.

0.2.1.6 Observations & calculations

It includes tabulation of observed data and calculations are required to be made for the meaningful analysis of results. Formulae involved in calculations need to be mentioned along with a sample of calculations. Graphical representation is a more effective way (than tabulation) of the presentation of results.

0.2.1.7 Conclusions

The conclusion expresses the main points (one or two) of the final results the lab.

0.2.1.8 Discussion

In this section you are supposed to justify your results. The expected results need to be justified with the help of some standard references. Reasons should be mentioned for the unexpected results. In this case all possible sources of error need to be looked at while giving consideration to the individual contribution of each source of error towards the overall error in the final results. Comparison of results with similar investigations (already made using same or different technique) is an essential component of the discussion section of a report.

0.2.1.9 References

Whatever information (other than own work of present report) has been used in writing of report needs to be properly referred (using a standard format of referring a book, a paper of a journal, a paper of a conference and information on a website). It is not sufficient to put a list of references at the end of a report. These references should also appear as numbers in square brackets in the main body of report.

0.2.2 Format

From **Semester 1** to **semester 4**, the report to be submitted containing the content as mentioned above, should be hand written. For **Semester 5 to Semester 8**, report to be submitted should be written on computer.

The following format should be followed for writing report on computer

Title page should always be documented on computer.

- **Font** should be **Times New Roman** (Whole Report)
- **Line Spacing** = 1.15 (whole report)
- **Title** should be of **font size = 16, Bold,**
- **Heading 1** should be of **font size = 14, Bold**
- **Heading 2** should be of **font size = 13, Bold**
- **Heading 3** should be of **font size = 12, Italic, Bold**
- **Page #** should be added.
- List of figure, List of table and Table of content**.**

0.2.3 Caption

For table: Above the Table aligned in center with table. **Font size: 10**

For Figure: Below the Figure aligned in center with figure. **Font size: 10**

0.2.4 References

Should be added in **IEEE format** using Endnote/word.

0.3 General Guidelines in a Lab for safety

The following guidelines are to be followed in a lab.

- No Laboratory work should be carried out without supervision of the Instructor or Lab technician.
- Do only experiment assigned to you and do not perform unauthorized experiment by yourself.
- Do not play with the equipment that are not part of experimental setup.
- Never leave an in progress experiment unattended.
- Don not exceed voltage limits of devices when plugging them into electrical outlets.
- Don not try to repair or modify any lab equipment.
- Always wear a protective lab coat/overall and safety shoes. Long hair should be tied back.
- Be alert to unsafe conditions and actions and call them to the attention of the instructor immediately.
- Be careful not to touch any heated surfaces as they might cause a burn.
- Don’t touch live conductor or wire with the bare hand.
- Don’t work in lab all alone.
- Report all damages to lab instructor immediately.
- Leave equipment in proper places at the end of your experiments and cleanup.
- After completion of the experiments, return the items borrowed, if any.
- Don’t run or paly in the lab.
- Eating drinking, smoking or chewing of gum is not permitted in the laboratory.
- Don’t use cell phones inside the laboratory.
- Everyone is responsible for housekeeping and cleaning up after themselves. Aisles and doorways, including access to the service hallway and electrical boxes, are to be kept clear for purposes of safe passage.
- Report any cases of vandalism or theft to your instructor or staff member.
- Students should not perform any type of maintenance on equipment in the lab without prior authorization and direct supervision of the lab manager.
- Use appropriate safety equipment for the task at hand (i.e. safety glasses, ear protection, gloves). See your instructor or a staff member for guidance.
- In case of fire or hazardous chemical spill evacuate the premises immediately.

Experiment 1. To calibrate pressure measuring devices using mercury manometer.

1.1 Learning Objectives

To compare methods of measuring pressure.

To calibrate pressure transducer and bourdon gauge using mercury manometer.

1.2 List of equipment

Bourdon gauge

Calibration bench + Compressor

Pressure Transducer

1.3 To compare methods of measuring pressure

In Pressure calibration bench, multiple methods of measuring pressure are available as listed below.

i) Mercury Manometer (0-760mm)
ii) Water manometer (0-200mm)
iii) Inclined manometer (0-75mm)
iv) Pressure transducer (Analog output potentiometer) (0-2 bar)
v) Bourdon gauge (-1 to 1bar)

Any of the above methods can be used to measure pressure and compared with each other.

1.3.1 Procedure

1.3.1.1 To measure pressure using Mercury manometer/water Manometer/Inclined Manometer

1. Turn the pump on. The pump takes air from atmosphere and compresses it to higher pressure.
2. Connect the pressure outlet from the compressor to the limb of mercury manometer. For pressure above atmospheric pressure outlet to be connected to limb of manometer containing higher mercury level. In case of vacuum, the pressure outlet to be connected to limb of manometer containing lower mercury level.
3. The pressure to be measured should lie within pressure measuring limits of particular device.
4. Measure the difference in height after applying pressure. And convert it into pressure.

5. Use step 1-4 for water manometer and inclined manometer. For inclined manometer. Angle is to be accommodated in pressure calculations.

1.3.1.2 To measure pressure using pressure transducer

1. Turn the pump on. The pump takes air from atmosphere and compresses it to higher pressure.
2. Connect the pressure outlet from the compressor to the inlet of pressure transducer.
3. The pressure to be measured should lie within pressure measuring limits of particular device.
4. Measure the pressure from analog dial gauge.

1.3.1.3 To measure pressure using Bourdon gauge

1. Turn the pump on. The pump takes air from atmosphere and compresses it to higher pressure.
2. Connect the pressure outlet from the compressor to the inlet of bourdon gauge.
3. The pressure to be measured should lie within pressure measuring limits of particular device.
4. Measure the pressure from dial.

1.3.1.4 Calibration

1. The reading from mercury manometer to be used as reference for comparison and calibration of other pressure measuring devices such as pressure transducer and bourdon gauge.
2. Calculate error in the form of percentage.

1.4 Observations and Calculations

$$Density\ of\ Mercury\ =\ 13000\frac{kg}{m^3}$$

$$Density\ of\ water = 1000\frac{kg}{m^3}$$

$$anlge\ of\ tilt\ of\ inclined\ manometer = 30^o$$

$$Pressure = \rho g \Delta h$$

Transducer				
Sr. #	**Pressure (bar)**	**Manometer (mm of Hg)**	**Manometer (bar)**	**%age error**
1.				
2.				
3.				
4.				
5.				
Bourdon gauge				
Sr. #	**Pressure (bar)**	**Manometer (mm of Hg)**	**Manometer (bar)**	**%age error**
1.				
2.				
3.				
4.				
5.				
Bourdon Gauge (Inlet vacuum)				
Sr. #	**Pressure (bar)**	**Manometer (mm of Hg)**	**Manometer (bar)**	**%age error**
1.				
2.				
3.				
4.				
5.				

1.5 Graphs

Plot graphs of pressure from pressure transducer and bourdon gauge against the values from mercury manometer.

1.6 Results and Discussion

Experiment 2. Study of Vernier height gauge

2.1 Learning Objective

To measure height of an object

To make graduations on an object

To find center of an object

2.2 List of Equipment

Vernier height gauge

Objects for measurement and graduation

2.3 Procedure

1. Measure the temperature at which readings are taken. Preferably the temperature should be 20^{o}C.
2. Calculate the least count of the gage and Check the scale for any zero error.
3. The Vernier height gauge and datum of object from which measurement is being made, be placed on very flat surface.
4. To measure the height, place the measuring end of scriber firmly against the object. The force should not be too high to damage the tip of scriber.
5. Measure the main scale reading and the Vernier scale reading. The height can be found by following formula.

$$height\ from\ datum\ = Main\ Scale\ Reading + (vernier\ scale\ reading \times least\ count)$$

6. Now to mark the center on the object, divide the height by 2.

$$center\ height\ from\ datum = \frac{height}{2}$$

7. If the center height come out to be xx.yy, Use following formula to get the number of divisions to be moved on Vernier gauge to get required center height.

$$No\ of\ Divisions = xx + \frac{yy}{Least\ count}$$

8. Move the scriber to the no of divisions got from above formula. Use fine tuning screw to move scriber exactly to required height.
9. Use scriber to mark the center on object with respect to datum.
10. To inscribe graduation line on object at given height. Use steps from 7 to 9 in procedure.

2.4 Precautions

1. Minimal touch of hand is recommended to avoid change in reading due to heat from hands.
2. The surface at which Vernier height gauge and object are placed should be flat.
3. Do not exert extreme pressures during measurement that may lead to damage of equipment.
4. Place equipment back immediately in box after use.
5. Do scratch and blow the equipment.

2.5 Results and Discussion

Experiment 3. Study of block/slip gauge

3.1 Learning Objectives

To calibrate the precision measuring instrument i.e. Vernier caliper

3.2 List of Equipment

i) Gauge block set
ii) Vernier Calipers
iii) Grease

3.3 Theory

3.3.1 Wringing

Wringing is a process by which the surface roughness and surface flatness slip gauge is checked before calibration of equipment. In wringing two gauge blocks are slide to each other such that they cling to each other with any external force applied. He process has following steps.

i) Use an oil pad to apply layer of oil on the surfaces of gauge block.
ii) Use dry pad to remove extra oil from the surfaces. The maximum oil spread allowed is 20% of surface.
iii) Slide the two block into a cruciform with slight pressure. Then rotate block such that they become parallel to each other. If pressure remove, the blocks should cling to each other.

3.4 Procedure

1. Measure the temperature at which test is being performed. Temperature recommended is 20^{o}C.
2. Take two blocks from set with known dimensions.
3. Join the surfaces using wringing process as explained earlier.
4. Now Use Vernier caliper to measure the dimensions of the joined blocks.
5. Calculate the difference between Vernier reading and actual reading to get the %age error in Vernier caliper.

3.5 Precautions

1. Hold the block gently with gloves wear on hands.
2. Touch the block minimally to avoid error due to temperature change.
3. Place the blocks immediately back after use.

3.6 Results and Discussions

Experiment 4. Study of Feeler gauge, Inner outer gauge, dial gauge, dial bore gauge, thread pitch gauge, go/No go gauge, snap gauge, tri square.

4.1 Learning Objectives

1. To measure of gap width using feeler gauge
2. To measure internal and external dimensions using inner outer gauge
3. To measure thread pitch and compare it with standard values.
4. To measure very fine changes in dimensions from required value using dial gauge.
5. To measure very fine changes in dimensions of internal diameter from required value using dial bore gauge.
6. To understand use of snap gauge and go/ no go gauge for quality assurance in production.
7. To define perpendicularity of an edge using trisquare.

4.2 List of equipment

a. Feeler gauge
b. Inner outer gauge
c. Dial gauge
d. Dial bore gauge
e. Thread pitch gauge
f. Go/No go gauge
g. Snap gauge
h. Tri-square.

4.3 Procedure

4.3.1 Feeler gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20^{o}C.
2. Spread out the wires or blades and read the marking on them that indicate diameter or width respectively.
3. Select the part to be checked and make sure it is clean.
4. Choose one of the smaller blades and try to insert it in the gap on the part. If it slips in and put easily.
5. Select the blade with larger size until the blade enters the gap with gentle pressure.
6. It is the exact width of that gap. Gauges can be stacked to get an intermediate value if required.

4.3.1.1 Precautions

- Strip of hardened steel may cut through skin if not handled properly

4.3.2 Internal and External Calipers

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. The tips of the internal and external calipers are adjustable to fit across the point to be measured internal or external to geometry respectively.
3. Caliper is then removed and distance read by measuring the tip distance using measuring instrument like Vernier caliper, ruler etc.

4.3.3 Trisquare

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Place the trisqurae between the surfaces of object that are to be chucked for perpendicularity.
3. See the visually if there is any gap between the surfaces and the edges of trisquare.

4.3.4 Thread Pitch gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Unfold a leaf from the gauge set.

3. Press the serrated edge gently against the threads.
4. Check the fit between the serrated edge of gauge and the threads.
5. Continue this process until the serrated edge leaf from gauge set exactly matches with the thread of object.
6. If fit properly together, read the stamped reading on the leaf. It will represent the thread pitch of your object.

4.3.5 Go/No go Gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Select the required diameter of the gauge.
3. Mount it on the rods with help of screws.
4. Insert it inside the hole.
5. If the gauge enters hole with slight pressure meaning that walls of gauge touch the walls of hole. Then hole's dimensions are acceptable.
6. If gauge slips freely in the hole or does not enter the hole with gentle pressure then hole does not have required dimensions.

4.3.6 Snap Gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Adjust the maximum and minimum allowable diameter of adjustable snap gauge. Test the required objects with the help of it by passing it through gap of gauge.
3. Those with diameter smaller than minimum allowable diameter wills slip through easily and those with larger diameter than maximum limit will not pass through gap of gauge or will require extreme pressure, will be out of limit of required dimensions and will be rejected.

4.3.7 Dial Bore gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Set the actuating plunger on the inner surface of the whole. Set the needle to zero on the dial using adjustment screw.
3. Move the plunger along the inner circumference to see the deflection that will represent the error in the hole diameter at certain depth.

4. Repeat this procedure for multiple depths. If the deflection is above/below the allowable limit the part is rejected.

4.3.8 Dial Gauge

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Touch the needle of dial gauge on the object whose deflection is to checked.
3. Set the deflection as zero. And move body surface with respect to the needle at different locations.
4. Observe the needle movement. If the deflection is above or below the allowable limit. The part is rejected.

4.4 Precautions

i) Never use the gauges on running machinery.
ii) Do not put high pressure on the gauges as it may change the geometry of gauge leading to error.
iii) Do not touch gauges frequently as temperature rise due to human touch may lead to error.
iv) Clean the gauges properly before and after use.
v) Place the gauges immediately in their respective box after experiment.

4.5 Observation and Calculation

4.6 Results and Discussion

Experiment 5. Study of bevel Protractor

5.1 Learning objective

To Measure of angles between the two edges/ surfaces using bevel protractor.

5.2 List of Equipment

Bevel Protractor

5.3 Procedure

1. Measure the room temperature at which experiment is being performed. Recommended temperature is 20oC.
2. Check the zero error in the bevel protractor. And find least count of protractor.
3. Align the beam and the swivel plate with edges of part between which the angle is to be measured.
4. Read the main scale to get the degrees. The value will be whole degree division surpassed zero line of Vernier caliper.
5. To read the Vernier scale reading, Read the value of division of Vernier scale at which division of minute scale of main scale is exactly matched.
6. Multiply the Vernier scale reading with least count to get the minutes.

5.4 Precautions

i) Read the main scale and Vernier scale readings carefully.
ii) Place bevel protractor in front of line sight to avoid parallax error.
iii) Blades of protractor should fit properly to sides of edges of the object.

5.5 Observations and Calculations

5.6 Results and Discussions

Experiment 6. Study of gear tooth thickness gauge

6.1 Learning objective

To Measure the thickness of tooth of gear at various heights.

6.2 List of Equipment

Gear tooth thickness gauge

6.3 Procedure

1. Measure the temperature at which measurement are being taken. Recommended temperature is 20^{o}C.
2. Check the zero error in both scales i.e. depth measuring scale and thickness measuring scale by fully closing the jaws together.
3. Measure the least count for both scales on gauge.
4. Open the jaws of thickness measuring scale. Now set the height using height defining scale to point at which thickness is to be measured (preferably at Pitch circle position). Close the jaws of thickness measuring scale with gentle pressure so that jaws have firm contact with tooth.
5. Read the main scale reading for both tooth height and tooth thickness scale. Read the Vernier scale of both scales on the gauge.
6. Use following formula to get the thickness of tooth and height at which thickness is measured.

$$Value \ = Main\ Scale\ Reading + (vernier\ scale\ reading \times least\ count)$$

6.4 Precautions

i) Minimal touch of hand is recommended to avoid change in reading due to heat from hands.
ii) Do not exert extreme pressures during measurement that may lead to damage of equipment.
iii) Place equipment back immediately in box after use.
iv) Avoid parallax error while taking reading.
v) Do scratch and blow the equipment.

6.5 Observations and Calculations

6.6 Results and Discussions

Experiment 7. Temperature calibration using temperature calibration unit

7.1 Learning objective

To compare different methods of Temperature measurement i.e. alcohol thermometer, bimetallic strip, resistance thermometer and thermocouple.

To calibrate different thermometers using Alcohol thermometers.

7.2 List of Equipment

Temperature calibration unit

7.3 Procedure

1. Fill the water bath with water.
2. Set the temperature range and turn the thermostat on. Make sure that all thermometers are dipped in water properly.
3. Make sure to stir the water during heating for uniform temperature throughout water bath.
4. After reaching the maximum set temperature, thermostat will turn off the heater.
5. Note value of temperature using all four type of thermometers.
6. Now increase the temperature range using thermostat and repeat the steps from 2 to 5.
7. Alcohol thermometer, bimetallic strip and thermocouple output readings are in ^oC, while resistance thermometer show reading in Ω. This reading is converted into ^oC using calibration charts.
8. To calibrate the bimetallic strip, thermocouple and resistance thermometer using alcohol thermometer by plotting temperature values of each against readings of alcohol thermometer and get equation.

Note: Least count of thermometer, thermocouple and bimetallic strip is 1^oC while for resistance thermometer it is 0.1^oC.

7.4 Precautions

1. Do not put finger in water bath.
2. Do not stir water violently.
3. Take the readings of glass thermometer carefully.
4. Handle the apparatus with care.

5. Let the system be steady before taking readings.

7.5 Observations and Calculations

Temperature Readings				
Sr. #	**Alcohol Thermometer (ºC)**	**Thermocouple (ºC)**	**Bimetallic Strip (ºC)**	**Resistance Thermometer (ºC)**
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

7.6 Graphs

Plot the graphs between thermocouple, resistance thermometer and bimetallic strip against the alcohol thermometer to get calibration equations.

7.7 Results and Discussions

Experiment 8. Study of Vernier caliper, Vernier Micrometer, Vernier depth gauge and inner micrometer.

8.1 Learning Objective

To study working of Vernier caliper, Vernier Micrometer, Vernier depth gauge and inner micrometer. To measure inner and outer linear dimensions of objects using Vernier caliper, Vernier Micrometer, Vernier depth gauge and inner micrometer

8.2 List of Equipment

i) Vernier caliper
ii) Vernier Micrometer
iii) Vernier depth gauge
iv) Inner micrometer

8.3 Procedure

8.3.1 Vernier caliper

1. Measure the temperature at which readings are taken. Preferably the temperature should be 20^oC.
2. Calculate the least count of the Vernier caliper and Check the scale for any zero error.
3. Fix the object between jaws such that object may come out if slight pressure is applied.
4. Measure the main scale reading and the Vernier scale reading. The height can be found by following formula.

$$value \ = Main\ Scale\ Reading + (vernier\ scale\ reading \times least\ count)$$

8.3.2 Screw gauge

1. Measure the temperature at which readings are taken. Preferably the temperature should be 20^oC.
2. Calculate the least count of the screw gauge and Check the scale for any zero error.
3. Fix the object between jaws such that object may come out if slight pressure is applied.
4. Measure the main scale reading and the circular scale reading. The dimension can be found by following formula.

$$dimension\ value \ = Main\ Scale\ Reading + (circular\ scale\ reading \times least\ count)$$

8.3.3 Vernier Depth gauge

1. Measure the temperature at which readings are taken. Preferably the temperature should be 20^{o}C.
2. Calculate the least count of the Vernier depth gauge and Check the scale for any zero error.
3. Apply the stem for depth measurement to point up to which depth is be measured.
4. Fix moving scale with the help pf screw.
5. Remove the gauge and measure the main scale reading and the circular scale reading. The dimension can be found by following formula.

$$dimension\ value \ = Main\ Scale\ Reading + (vernier\ scale\ reading \times least\ count)$$

8.3.4 Inner Micrometer

1. Measure the temperature at which readings are taken. Preferably the temperature should be 20^{o}C.
2. Calculate the least count of the inner micro meter and Check the scale for any zero error.
3. Rotate the circular scale to move the jaws to inner diameter.
4. Measure the main scale reading and the circular scale reading. The dimension can be found by following formula.

$$dimension\ value \ = Main\ Scale\ Reading + (vernier\ scale\ reading \times least\ count)$$

8.4 Precautions

i) Minimal touch of hand is recommended to avoid change in reading due to heat from hands.
ii) Vernier depth gauge to be inserted at right angle to avoid error in calculation.
iii) Do not exert extreme pressures during measurement that may lead to damage of equipment.
iv) Place equipment back immediately in box after use.
v) Do scratch and blow the equipment.
vi) In screw gauge use ratchet to tighten instead of spindle.

8.5 Observations and Calculations

8.6 Results and Discussion

Appendix

Appendix A

Program Learning Outcomes (PLOs)

On the basis of the Knowledge Attributes defined in the Washington Accord, twelve (12) Program Learning Outcomes, also known as Graduate Attributes, are listed below:

(i) **Engineering Knowledge**: An ability to apply knowledge of mathematics, science and engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

(ii) **Problem Analysis**: An ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

(iii) **Design / Development of Solutions**: An ability to design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

(iv) **Investigation**: An ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.

(v) **Modern Tool Usage**: An ability to create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

(vi) **The Engineer and Society**: An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.

(vii) **Environment and Sustainability**: An ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.

(viii) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

(ix) **Individual and Team Work**: An ability to work effectively, as an individual or in a team, on multifaceted and/or multidisciplinary settings.

(x) **Communication**: An ability to communicate effectively, orally as well as in writing on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentations, make effective presentations, and give and receive clear instructions.

(xi) **Project Management**: An ability to demonstrate management skills and apply engineering principles to one's own work, as a member and/or leader in a team to manage projects in a multidisciplinary environment.

(xii) **Lifelong Learning**: An ability to recognize importance of, and pursue lifelong learning in the broader context of innovation and technological developments.

Appendix B

Details of Domains

Cognitive		Affective		Psychomotor	
Level 1	Knowledge	Level 1	Receiving	Level 1	Perception
Level 2	Comprehension	Level 2	Responding	Level 2	Set
Level 3	Application	Level 3	Valuing	Level 3	Guided Response
Level 4	Analysis	Level 4	Organization	Level 4	Mechanism
Level 5	Synthesis	Level 5	Characterization by value or value complex	Level 5	Complex over response
Level 6	Evaluation			Level 6	Adaption
				Level 7	Organization

Appendix C

Lab Rubrics for ME-308L Measurement & Instrumentation Lab

CLOs	Criteria	Poor (0 to 4)	Satisfactory (5-6)	Good (7-8)	Excellent (9-10)
CLO-1	Apparatus Handling, Experiment Performance and Calculations	No knowledge of apparatus, experiment not performed, nor any calculations done	Knows basic operation of the apparatus, performed the experiment with major errors in calculations	Can handle the apparatus well, experiment completely performed, and calculations have few mistakes	Fully understands the complete operation of the apparatus, experiment performed, and all calculations are correct
	Planning and Execution of an Experiment [OEL]	Experiment not planned for proper execution	Experiment planned but not executed properly	Experiment planned and executed but slight omissions	Experiment correctly planned and executed
CLO-2	Communication [Report]	Report neither covers technical details of experiment nor according to format	Correct report submitted according to format but not covering essential technical details	Report well written technically but format not completely followed / slight mistakes	Well-composed flawless report covering technical aspects of experiment
	Communication [Viva]	Either does not understand or cannot communicate concepts related to experiment	Understands the concepts related to experiment but does not communicate in technical terms	Understands and able to communicate the learned concepts but with slight mistakes	Fully understands all the concepts and can express them technically
CLO-3	Punctuality, Teamwork and Safety	Arrives too late for experiment with disregard to teamwork or safety	Arrives little late for experiment, somewhat adheres to teamwork and safety	Punctual but slightly lacking in teamwork and safety consciousness	Punctual, works as a team and adheres to safety instructions