# University Of Jordan
## Faculty of Engineering and Technology
## Industrial Engineering Department

# Measurements Lab
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University Of Jordan
Faculty of Engineering and Technology
Industrial Engineering Department

# Measurement Lab.

EXPERIMENT 1 :

## LINEAR MEASUREMENT

Student Name :
Student No. :

GROUP ( )

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## OBJECTIVE:

To familiarize the student with the types, applications of calipers, micrometers & measurements.

At the completion of this experiment, the student will be able to:

- Get familiar to the variety of the linear measurement tools, and know the type of a measurement tool needed to achieve a certain measurement.
- Students will seek more efficient means of measure.
- Take linear measurements with a certain accuracy depending on the instrument being used
- Clean, care for and store calipers, micrometers and dial indicators.

## APPARATUS:

Vernier Caliper

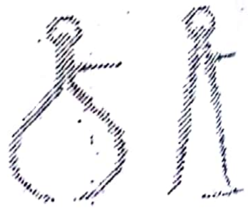
a) Vernier caliper
b) Dial caliper
c) External micrometer
d) 2-point inside micrometer

## 1. Calipers:

*General definition of a caliper:*

1. An instrument consisting essentially of two curved hinged legs, used to measure thickness and distances. Often used in the plural.

2. A large instrument having a fixed and a movable arm on a graduated stock, used for measuring the diameters of logs and similar objects.



3. A vernier caliper.

*General specifications & functions of a caliper:*

- All Stainless Steel construction
- Used to measure inside dimensions
- Used to measure outside dimensions
- Used to t measure step dimension
- Convenient thumbscrew to lock a measurement in place
- *Accuracy equation*

$$Accuracy = \frac{1 \text{ division main scale}}{\text{no. of divisions on vernier scale}}$$

*Two types of calipers are to be discussed in this experiment:*

### (1.1).The vernier caliper :

The Vernier Caliper shown in fig. (1.1.1) is a precision instrument that can be used to measure internal and external distances extremely accurate.

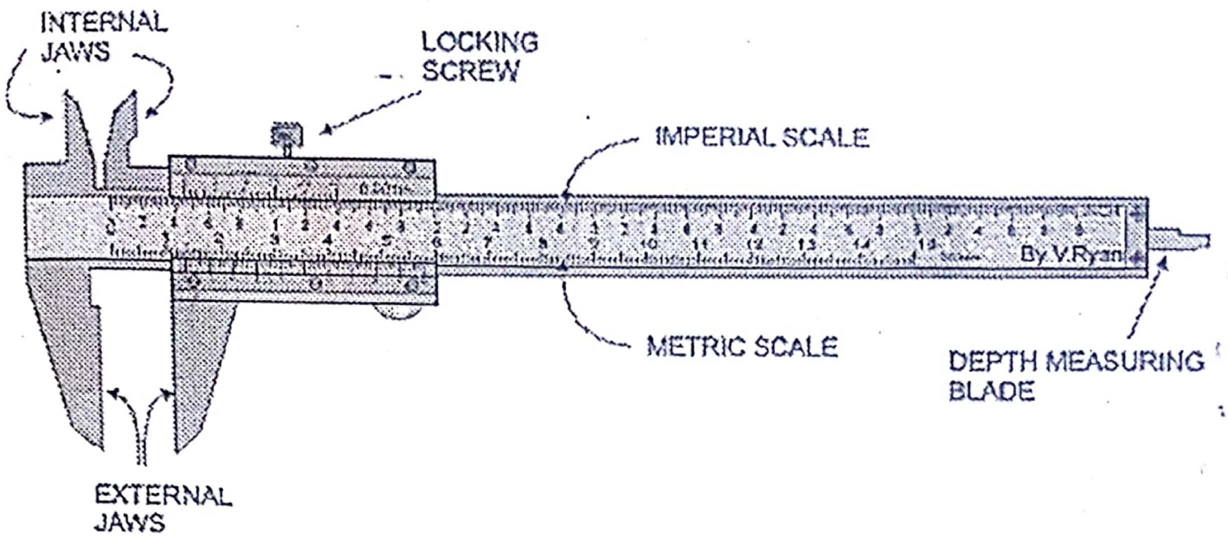



**Fig. (1.1.1):a Vernier Caliper**

## Description:

- A vernier caliper has two scales, a *main* scale and a *vernier* scale.
- These two scales move past each other, usually on a slide.
- When the measurement is taken, the zero point of the vernier scale lies at the true datum of the measurement.
- Main scale (on the larger, fixed portion of the caliper) gives the most significant digits of your reading.
- The vernier scale (on the smaller moving portion of the caliper) gives the least significant digits in the reading and

subdivides a mark on the main scale into 10, 20, 50 subdivisions.

- Notice that ten tick marks in the sliding scale are the same width as nine ticks marks on the fixed scale.
- The smallest division on a scale is the least count of it. On the fixed scale (main scale) the least count is **1** mm, while on the sliding scale (vernier scale) the least count is **.02** mm (50 divisions to represent 1 cm).
- Most direct reading calipers have an arrow sliding blade attached to the sliding jaw. it permits the dial caliper to be used as an efficient and accurate depth gauge.

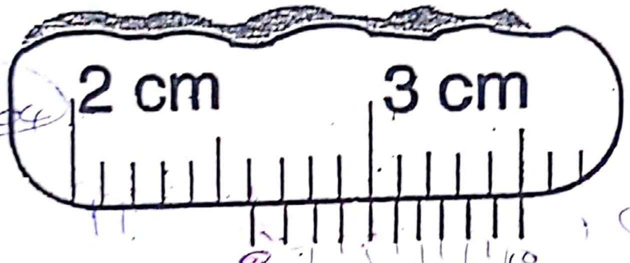
## How to use &read a vernier caliper:

**To start:**

- Place the object between the calipers jaws.
- Close the jaws gently on the part to be measured.
- When you are measuring a round cross sectional parts, make sure that the axis of this object is perpendicular to the caliper, to ensure measuring the full diameter.
- Lock the final locking screw and remove the object

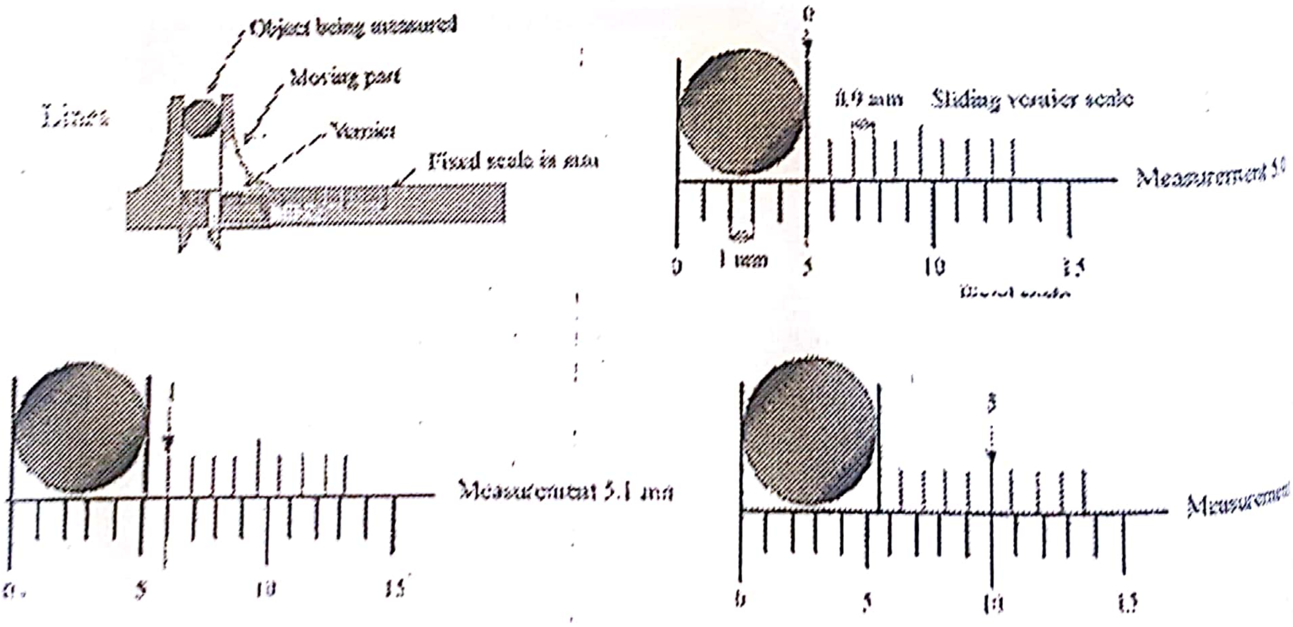
Then:

- Read the centimeter mark on the fixed scale to the left of the 0-mark on the vernier scale. (2 cm on caliper seen below).
- Find millimeter mark on the fixed scale that is just to the left of the 0-mark on the vernier scale. (2.6 cm).
- Look along the ten marks on the vernier scale and the millimeter marks on the adjacent fixed scale, until you find the two that most nearly line up. Here it is (0.04 cm).
- To get the correct reading, simply add this found digit to your previous reading. (2.64 cm).
- If two adjacent tick marks on the sliding scale look equally aligned with their counterparts on the fixed scale, then the reading is half way between two marks. If the 4th and 5th looked to be equally aligned with their counter parts then the reading is (26.45±.05) mm.
- If the reading is a nice number such as (2, 6, 9….etc.) don't forget to place the zero decimal after the reading plus to the error introduced (I.e. 2.000±.05).
- **Example:**




*Reading: 2.64*

- The vernier caliper is an extremely precise measuring instrument , the reading error is (1/20) mm=0.05 mm
- Note: for inside readings ,the thickness of the jaws must be added to the scale reading.




- Fig. (1.1.2): Further examples on using a Vernier Caliper.

*(1.2) Dial caliper:*

It can be described as a modified vernier caliper with gauges, which allows us to have a direct reading. It can be also provided with a digital indicator.

Because it is easier to read, the direct reading dial caliper is gradually replacing the standard vernier caliper.

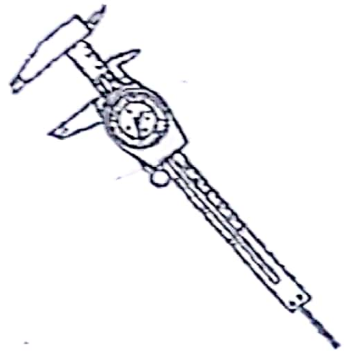


**Fig. (1.2.1) :Dial Caliper**

**Description:**

- Dial calipers are manufactured is inch &/or metric standards, and are available with digital readouts.
- A dial indicator, the hand of which is attached to a pinion is mounted on the sliding jaw.
- For metric dial caliper one revolution of the hand represents 2mm of travel, depending on the manufacturer. Therefore, each dial graduation represents .02mm maximum discrimination. Other type with 5mm move/rev & maximum of 0.05 mm.
- Most direct reading calipers have an arrow sliding blade attached to the sliding jaw (and dial).it permits the dial caliper to be used as an efficient and accurate depth gauge as introduced later
- The beam scale on the dial caliper is graduated only into 5mm and 10mm increment.
- The caliper dial is graduated into 100 dimensions.

How to use &read a dial caliper:

- Place the object between the calipers jaws.
- Close the jaws gently on the part to be measured.
- When you are measuring a round cross sectional parts, make sure that the axis of this object is perpendicular to the caliper, to ensure measuring the full diameter.
- Get the most significant digit from the main scale let us say (2.4 cm),then look at the dial gauge to take the least significant digits (as 1 division on the dial indicator equals .02 mm )so if we had 67 divisions on the dial then the least significant digit is = 67 *.02 = 1.28 mm.
- Finally to get your reading add the most and least significant , and take into considerations units. 24mm+1.28mm = 25.28mm ±0.05mm

How to care the calipers?
Regardless of what type you use:

1. Wash your hands before use.
2. Wipe the calipers components.
3. Do not drop or otherwise mishandle the caliper.

### *(1.3) Alignment principle:*

Abbe's principle states that:
"The maximum accuracy may obtain when the standard scale and the work piece being measured are aligned on the same line measurement." When the contact points of a micrometer are away from the axis of the graduations, as shown in the example, measurement error (e) will become significant. This case, a special attention must be paid to the measuring force.

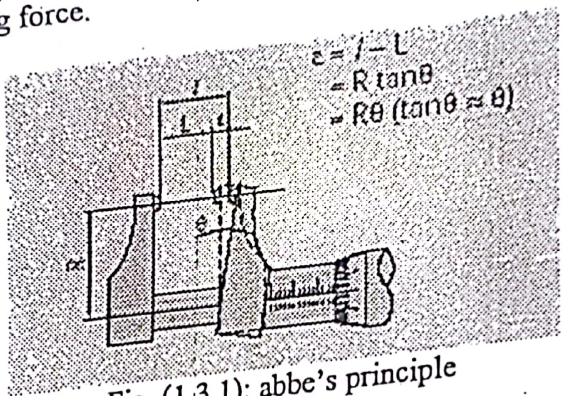



Fig. (1.3.1): abbe's principle

## 2.Micrometers:

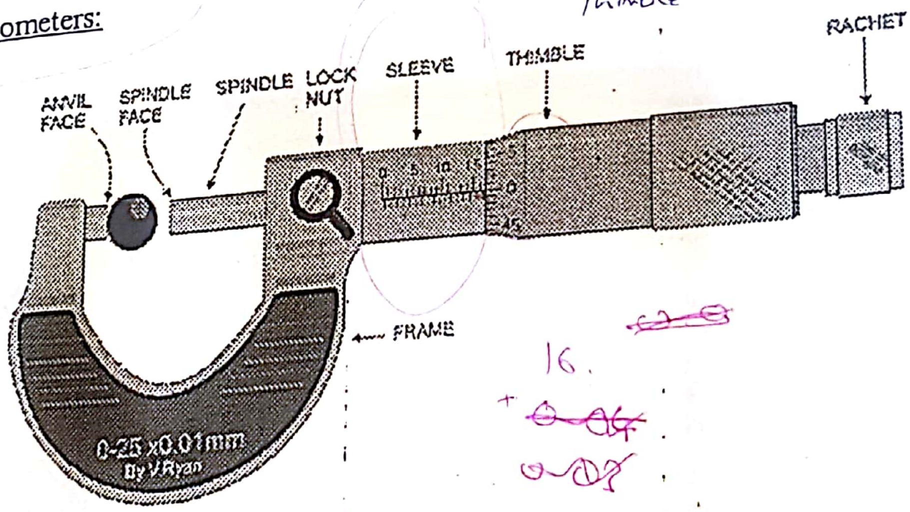



Fig.: (2.0.1): The micrometer calipers

A micrometer is a widely used device in mechanical engineering for precisely measuring thickness of blocks, outer and inner diameters of shafts and depths of slots. Micrometers have several advantages over other types of measuring instruments like the vernier, like:

- It measures greater precision than the caliper, but smaller ranges of lengths
- The vernier caliper does not give such accurate readings as micrometer because:

1. It is difficult to obtain a correct feel due to its size and weight.
2. The scales are difficult to read even with the aid of magnifying glass

Description:

- The tick marks along the fixed barrel of the micrometer represent halves of millimeters.
- One revolution of the knob exposes another tick mark on the barrel consequently the jaws will open another half millimeter.
- The moving barrel of the micrometer has 50 tick marks rapped around each tick mark represent 0.01 mm.
- Pitch, is the distance from point on one thread to a corresponding point on the next thread.
- Lead, is the distance to a thread advances axially in one compete revolution to turn.
- $$accuracy = pitch \times \frac{\text{no.of divs. On vernier scale}}{\text{no.of divs. On thimble scale}}$$
- Before using the micrometer, its accuracy must be verified.(as will be in the next section.).

***Accuracy verification of a micrometer:***

- Zero-checking:

zero checking is one way to determine the accuracy of a zero to one-2.54cm micrometer. Zero checking is exactly what it sounds like.

Zero checking is the condition where, the display of a zero to one-inch micrometer should show zero.

The steps are as follows.

1. Turn the thimble of the micrometer until the spindle is snug against the anvil.
2. Fine-tune the contact between the spindle and anvil with the ratchet stop until it clicks.
3. Check the reading.
4. If the reading is zero, the micrometer is ready to be used for measuring.

   If the reading u got does not equal zero(due to our capabilities of sight), use the following steps to correct the gage, then read the micrometer and subtract this offset from all the measurements been taken.

- Calibration:

Calibration is the process for insuring the accuracy of gages. The process involves a gage block and the micrometer. A gage block is a block made from steel that is cut to size with in a millionth of an (inch\cm). Gage blocks come in various sizes and are used to check the accuracy of measuring devices such as a micrometer.

If the reading you get from the micrometer is the gage block's dimension, you may begin using the micrometer for measuring. The micrometer may also be checked for calibration using other gage blocks within its range.

Using other blocks that fall within the range of the gage will test the gage's accuracy from one end of the spindle to the other. This may also uncover problems and explain why the gage is loosing accuracy. In the event that the display and the gage block dimension do not correspond, you will need to re-calibrate the micrometer.

Types of micrometers:

*There are three types of micrometers based on their application:*

- External micrometer
- Internal micrometer
- Depth micrometer

An external micrometer is typically used to measure wires, spheres, shafts and blocks.

An internal micrometer is used to measure the opening of holes, and a depth micrometer typically to measure depths of slots and steps.

How to use &read a Micrometer:

To start:

- Use the ratchet knob (cap) to close the jaws gently on the object to be measured. When the ratchet clicks the jaws are closed sufficiently.

Then:

**To read the distance between the jaws of a micrometer:**

- Get the reading from the fixed barrel ,while(1 div. = .5 mm), divisions
- Get the reading of the moving barrel while (1 div. = .01 mm)
- To get the final reading: simply add the two reading, and take into consideration the units

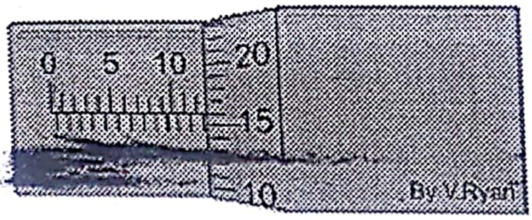
**Using Fig. (2.0.1) seen below:**

1. Read the scale on the sleeve. The example clearly shows12 mm divisions.

2. Still reading the scale on the sleeve, a further ½ mm (0.5) measurement can be seen on the bottom half of the scale. The measurement now reads 12.5mm.

3. Finally, the thimble scale shows 16 full divisions (these are hundredths of a mm).

The final measurement is 12.5mm + 0.16mm = 12.66 ± 0.005 mm




SLEEVE READS FULL mm = 12.00
SLEEVE READS ½ mm = 0.50
THIMBLE READS = 0.16
TOTAL MEASUREMENT = 12.66mm

Fig. (2.0.1)

How to care the micrometers:

- Before work makes sure that the object to be measured is fixed stationary (not moving).
- Avoid over tightening the micrometer. Such abuse to the micrometer will only do damage to the micrometer, or any other gage you may be using.
- Great care must be taken in using the micrometer caliper; A ratchet knob is provided for closing the caliper on the object being measured without exerting too much force.
- While you are using a micrometer, it would be mostly recommended to hold the frame with one hand and turning the knurled sleeve with the other hand.
- Damage can be caused to a micrometer if it is dropped. So it is recommended to make sure that the micrometer is in a safe place when it is not being used.
- Before you store a micrometer back the spindle away from the anvil wipe all exterior surfaces with a clean glove.

## (2.1)THE DEPTH GAUGE MICROMETER:

### Definition:

The depth gauge micrometer is a precision measuring instrument, used by engineers to measure depths of holes, slots, and recesses, the distance of stepped faces from each other and similar applications.

### Description:

- Each revolution of the ratchet moves the spindle face 0.5mm towards the bottom of the blind hole.
- **Fig (2.1.1)** below shows how the depth gauge is used. The ratchet is turned clockwise until the spindle face touches the bottom of the blind hole. The scales are read in exactly the same way as the scales of a normal micrometer. (Refer to the example about fig (2.0.1).

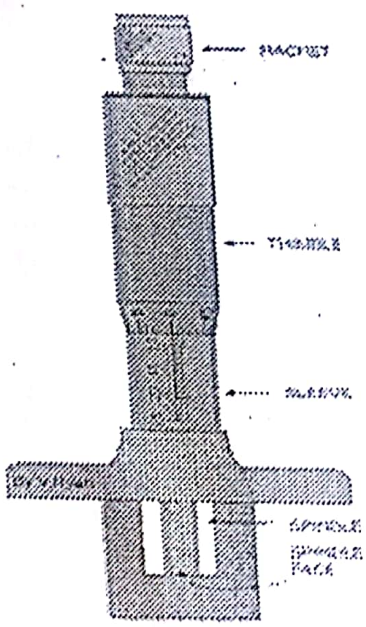


**Fig (2.1.1): depth-gauge micrometer**

(2.2) two-point inside micrometers

this micrometer is used for measuring the internal dimensions and graduated in 100's of a mm, this micrometer is available in two designs: fig(2.2.1)

1. One with jaws similar to vernier caliper and with a scale reading backwards.
2. The second is a straight bar with a micrometer barrel this type can b obtained with several interchangeable rods which allow a wide range of measurements.

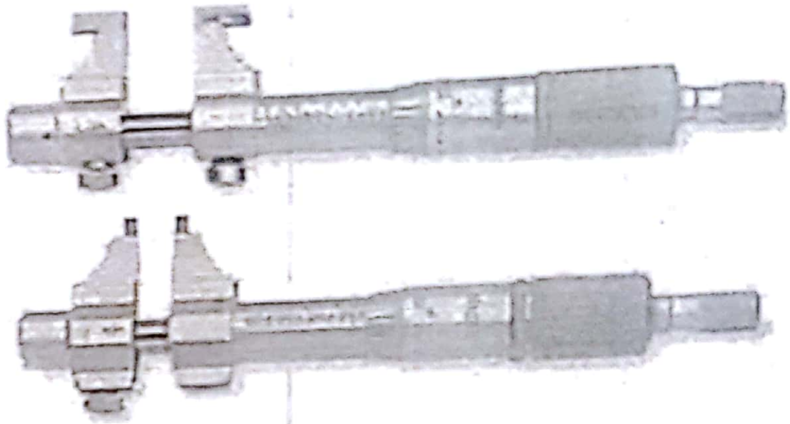


Figure (2.2.1): 2-point inside micrometer

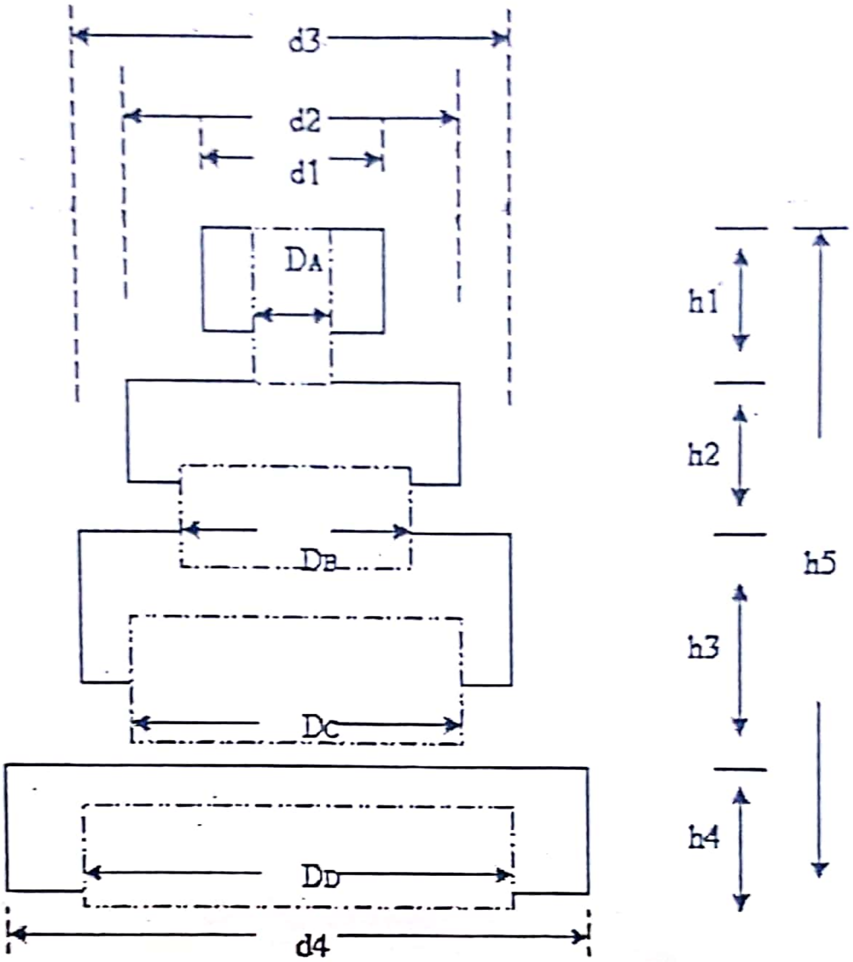
Description:

- This type of micrometer used for measuring inside diameters.
- The same principle application as for other micrometer.
- The reading of two point inside micrometer is taken in a similar manner are that of the depth micrometer.
- The reading increase as the thimble is screwed.

***PROCEDURE:***

- Inspect the tool to be used before using.
- Check its accuracy and zero alignment.(determine an offset).
- Clean the specimen to be used, with a soft cloth.
- Hold the tool in a proper way to start measuring.
- Take abbe's principle into consideration before taking a reading.
- Measure the dimensions of the specimen shown below with each of the following measuring devices (If it is possible):
  _Vernier Caliper, Dial. Caliper outside micrometer, 2-point inside micrometer &depth micro meter
- Make sure not to drop the measuring tool.
- Record you readings in table 1

- After measurements are taken ,make sure to leave the measuring device clean, and in a safe place




*RESULTS:*

| Measuring instrument | D1 | D2 | D3 | D4 | Da | Db | Dc | Dd | H1 | H2 | H3 | H4 | H5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vernier caliper | | | | | | | | | | | | | |
| dial | | | | | | | | | | | | | |
| Outside micrometer | | | | | | | | | | | | | |
| 2-point depth | | | | | | | | | | | | | |

Table 1

## DISCUSSION & CONCLUSIONS :

Caliper:

1. Does the vernier caliper conform to abbe's principle of alignment? Why?

2. Calculate the error of a vernier caliper?

3. What is the function of the sliding blade of the caliper?

4. what is a direct reading instrument, does that apply to the caliper?

5. What are the sources of error in reading a caliper?

6. What could happen if the locking screw is not used when measuring a distance with the vernier caliper?

7. Is the reading taken from a caliper in an inside measurement of an object is final? In this case is the caliper considered to be a comparator?

8. Is the vernier line standard or end standard?

9. What are the advantages of the vernier caliper over the micro meter?

Micrometers:

1. Draw a simple diagram representing the depth gauge micrometer and label the important parts.

2. How many screw threads are in each micrometer?

3. Does the external micrometer Obeys the abbe's principle? How?

4. What is the total length approached by the moving barrel when it rotates a complete revolution?

5."over tightening the micrometer, will only do damage to the micrometer, or any other gage you may be using." Explain.

4. Can this micro. Be used as comparators?

5. the accuracy of the micrometer depends on the accuracy of the screw threads, explain?

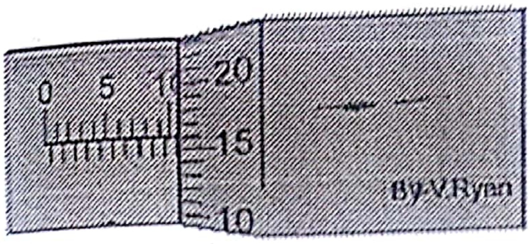
6. What are the factors governing the estimated reading?

7. What are the sources of error in reading a micrometer?

8. Is the spindle rotating or non rotating type? Name disadvantages of rotating type?

## EXTRA EXCERSISES:

**1. What s the reading indicated by the following micrometers?**



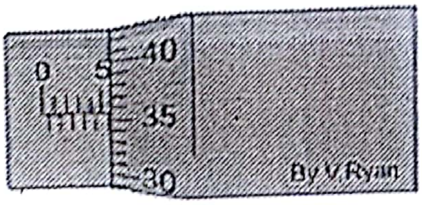


**answer:**

10
+0.16
6.16

**answer:**

16.01 0.16

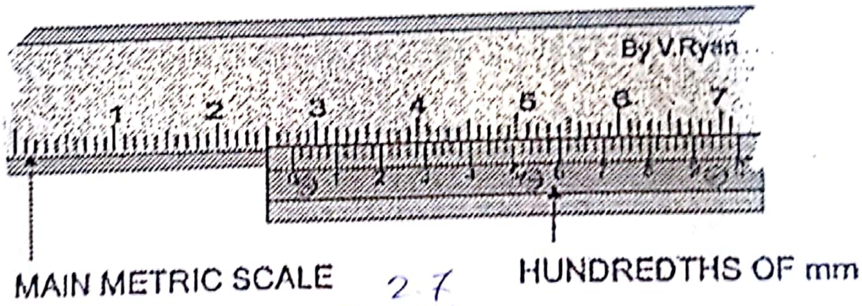



**answer:**

5.0 + 0.35

**2. What s the reading indicated by the following calipers?**

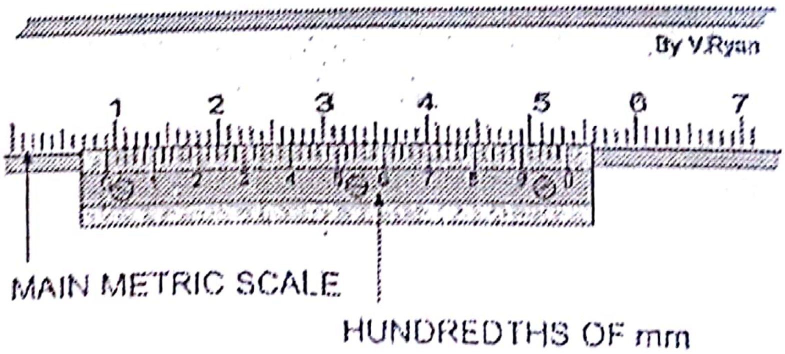
QUESTION 1:




27
+0.01

**answer:**

QUESTION 2:




**answer:**

University Of Jordan
Faculty of Engineering and Technology
Industrial Engineering Department

# Measurement Lab.

**EXPERIMENT 2 :**

## BLOCK GAUGES

**Student Name :**
**Student No. :**

**GROUP ( )**

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micro $10^{-6}$

## *OBJECTIVES:*

micron

-To familiarize students with types and applications of block gauges.
- To be able to calibrate linear measurements tools.
- Learn the correct ways of using them in measurements.
- Learn how to maintain them in the correct shape

## *INTRODUCTION:*

In industrial applications maximum accuracy must be met in order to produce reliable products.
What is the most accurate way to measure 5mm distance?
Using a steel rule, caliber, or micrometer?
When maximum accuracy needed the use of ordinary measuring tools is not a good approach, there for some other ways is introduced to give more accuracy such as block gauges.

Block gauges are practical length standards of industry. A modern end standard consists fundamentally of a block (slip) or bar of steel or cemented carbide -generally hardened- whose end faces are lapped flat and parallel within a few tenth of a micrometer.

***There are two types of length standards:***

1. Line standard or Engraved scale:

In which the unit length is defined as being the distance suitably engraved lines. Like the ruler you can measure 1cm or 1.5 cm that is the whole distance is divided into sub measurements units.

2. End standard:

In which the unit of length is defined as being the distance between the end faces of the standard, these take the form of either slip, so the whole piece can measure 5mm for example but not 4.5 mm.

Gauge blocks are good examples of end standards. The name end standards indicate that these consist of sets of standard blocks or bars, and to have the desired measurement we have to build a required length from the blocks. And they have the following characteristics:
-End standard are highly accurate
-End standard have a built in datum because there measuring faces are flat and parallel
-The accuracy of end and line standard is affected by the temperature they are calibrated at 20 °C.
-They are made in high-grade cast steel.

As motioned earlier, block gauges are standard bars made of hardened steel, which is heat treated. Its accuracy is 0.0005 mm. Its calibrated conditions: 20°c, 1 atm, and 60% relative humidity, they are specially machined and therefore they have the following characteristics:

1) Straightness
2) Flatness: the surfaces are made by a very accurate process named lapping therefore they are flat to a very high degree.

3) Parallelism: each tow surfaces or two lines are parallel to a very high degree.

But there is four types of block gauges differ by the degree of there accuracy, quality and roughness.

***Grades of gauge blocks:***

1. 00
2. Calibration: this grade provides the highest level of accuracy required in normal engineering practice and is intended for calibrating other blocks in conjunction with suitably accurate comparators. They are used where tolerance are 2 micrometer or less and are not inténded for generally gauge inspection.
3. 0
4. I
5. II

When the grades get larger the tolerance get larger and the price cheaper, the best and most expensive of all is grade 00.

***USING THE BLOCK GAUGES:***

Number of pieces in gauge blocks set can be:

1. 48 pieces in gauge block set
2. 87 pieces in gauge block set

The sizes found in 87 pieces gauge block set Grade II, which we use it in this experiment, are:

0.5, 1.0, 1.001-1.009 (by 0.001 steps),

1.10-1.19 (by 0.001 steps),

1.20-1.29 (by 0.001 steps),

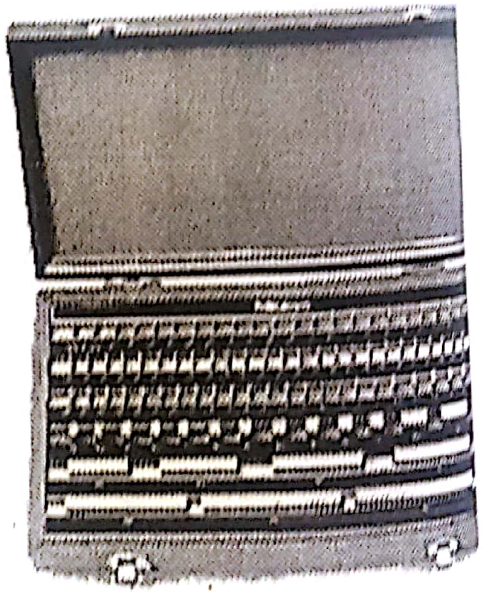
1.30-1.39 (by 0.001 steps),

1.40-1.49 (by 0.001 steps),

1.50, 2.0, 2.5, 3.0, 3.5, 4.0,

4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5,

8.0, 8.5, 9.0, 9.5, 10.0, 20.0,



30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0 and 100.0mm.

As can be seen from the figure the block gauges are fitted in a wooden box, for each of the blocks there is a special place with the length written on it.

Each block has two surfaces that have high lapping; you can distinguish them by noticing that they shine the most of the six faces. The length is taken between these tow surfaces which are parallel.

- ***Instructions for wringing together two slip gauges:***

1. Surfaces must be clean and free from burrs. They should be washed in petrol, benzene, carbon tetrachloride or other DE-greasing agents and wiped dry on a clean

cloth. Then be wiped with clean soft chamois leather. Slip gauges they should be held across one another at right angles and wiring them with a rotary motion; this reduces the amount of surface rubbing necessary.

2. A minute amount of grease or moisture must be present between the surfaces for them to wring satisfactory. Unless a very firm wring is obtained there is always the possibility that the wringing film maybe a micrometer thick.

- **Another way to assemble a gauge block:**

1. Remove the gauge blocks required from the protective case
2. Clean of the oil that they have been coated in using a special cleaner. It is acceptable to handle the blocks; in fact the oil from your hands will help them stick together.
3. One at a time, hold the blocks so that the faces just overlap, push the blocks together, and slide them until the faces overlap together. This will create a vacuum between the blocks that makes them stick together (this process is known as wringing).
4. Make required measurements with the gauge blocks, being careful not to damage the faces
5. Take the blocks apart, and apply the protective coating oil, and return them to their box.

In order to protect the blocks take the following points into consideration:
-Protect from dust, dirt and moister.
-Avoid magnetization.
-Handle lapped faces as little possible to prevent etching from finger acid; wipe all finger marks with chamois leather.
-Always wipe faces immediately before use even when it continuous.
-Always replace clean gauges in their box and close it after use. If gauges are not in frequent use they should be coated to prevent corrosion.
-Do not handle gauges above open box, they mat cause damage to other gauges if dropped.

It was mentioned earlier that we have to build the desired length of the blocks; the following example explains the procedure:
-Build a 30.967 mm using the minimum number of blocks.

30.967
**- 1.007**
29.960
**-1.090**
28.870
**-1.370**
27.500
**-7.500**
20.000

So we 5 blocks are used to build the desired length.

***APPARATUS:***

- Set of block gauges
- Granite surface plate

## *EXPERIMENTAL PROCERUDE:*

After being familiar with the blocks and the available rang of lengths complete the following procedure.

1-Use minimum number of block gauges to build the following size length and complete table1.

Table 1:

| # of gauges | 59.876 mm | 41.389 mm | 9.999 mm |
|---|---|---|---|
| 1st piece | | | |
| 2nd piece | | | |
| 3rd piece | | | |
| 4th piece | | | |
| 5th piece | | | |
| 6th piece | | | |

2-Complete the following table and Plot your results & determine the maximum error

Table 2:

| Standard block gauge mm | Standard block gauge with error mm | Reading of micrometer |
|---|---|---|
| 0.000 | 0+ 0.0005<br>0-0.0005 | |
| 3.000 | 3+ 0.0005<br>3-0.0005 | |
| 5.000 | 5+ 0.0005<br>5-0.0005 | |
| 10.000 | 10+ 0.0005<br>10-0.0005 | |
| 15.000 | 15+ 0.0005<br>15-0.0005 | |
| 20.000 | 20+0.0005<br>20-0.0005 | |

3-Take the piece which you want to measure its length and take its length by using vernier caliber (to take approximate length to easy the comparison )then we put it in a mechanical comparator and calibrate it to get error less than 0.01 mm. Now remove the piece and put block gauges until we reach the desire value. Then we take the reading of blocks.

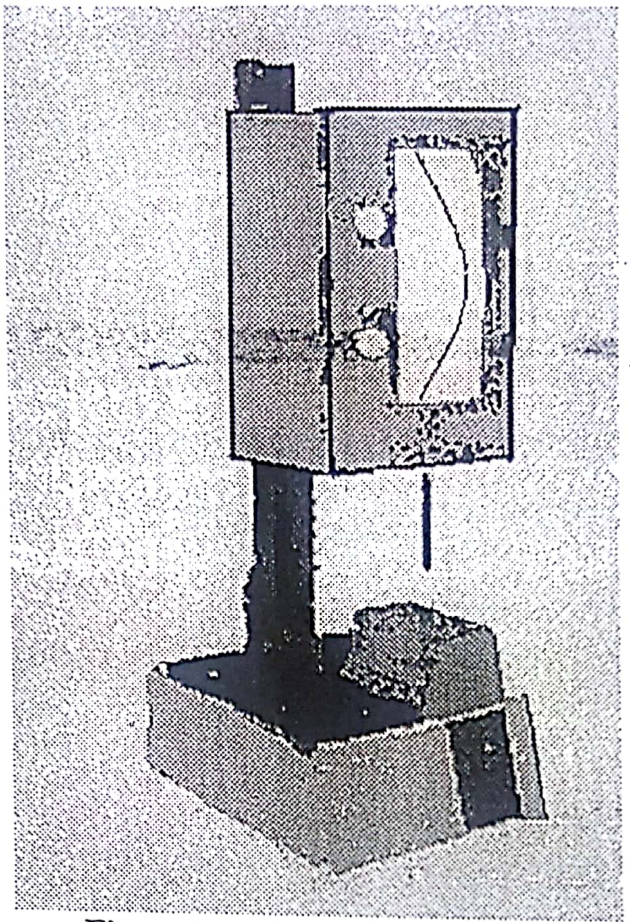


**Figure 1 mechanical comparator**

As seen in the figure the mechanical comparator is used to detect the correct number of blocks needed to the desired length, and it provides a rang of tolerance within the measurement is acceptable.

## DISCUSSION:

1. State the difference between end standard and line standard? And state the reason that make the end standard more accurate?
2. Stat the difference between the different grades of the blocks.
3. What is the accuracy of the block gauges? How did you reach the answer?
4. Why do we always choose the minimum number of blocks combination?
5. Why do we bather ourselves with how the blocks should be attached to each other?
6. Suggest other applications for block gauges?
7. In the comparator measuring method what do we compare with?

University Of Jordan
Faculty of Engineering and Technology
Industrial Engineering Department

# Measurement Lab.

EXPERIMENT 3 :

## AUTO COLLIMATOR

Student Name :
Student No. :

GROUP (          )

________________________________

________________________________

________________________________

________________________________

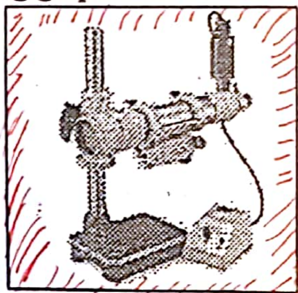
# Auto collimator

## Introduction

An autocollimator is an optical instrument that is used to measure small angles with very high sensitivity. As such, the autocollimator has a wide variety of applications including precision alignment, detection of angular movement, verification of angle standards, and angular monitoring over long periods.

## Objectives:

- To measure straightness of a beam with the use of Auto-Collimator.
- To identify the principle of Auto-Collimator device.
- To be able to draw conclusions about straightness error using graphical methods and least square method.



## Apparatus:

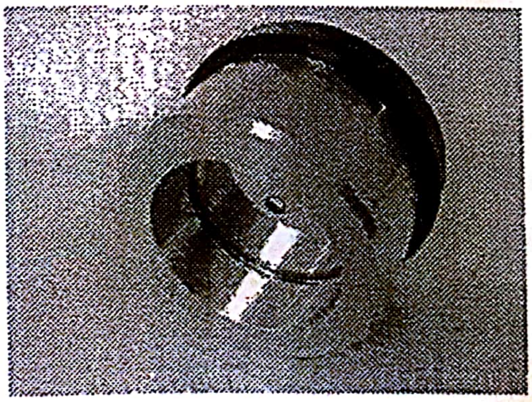
1) auto collimator
2) straight edge with 100mm marked intervals.

## Theory:

Auto-collimators are sensitive and inherently very accurate optical instruments for the measurement of small angular deviations of a light reflecting flat surface. The auto- collimator has its own target which is projected by collimated light beams on a remotely placed surface and the reflected target image is observed in the ocular of the instrument.

The auto-collimator is stationed at the end of the bed with a rigid support base. The movement of the reflector along the bed will cause the reflected image of the target to deflect according to the angular error of the bed.

The autocollimator is a flat mirror mounted in a short tube made to fit a Newtonian telescope focuser, and set accurately perpendicular to the tube's axis. Centered in it is a small peephole or pupil that you look through.



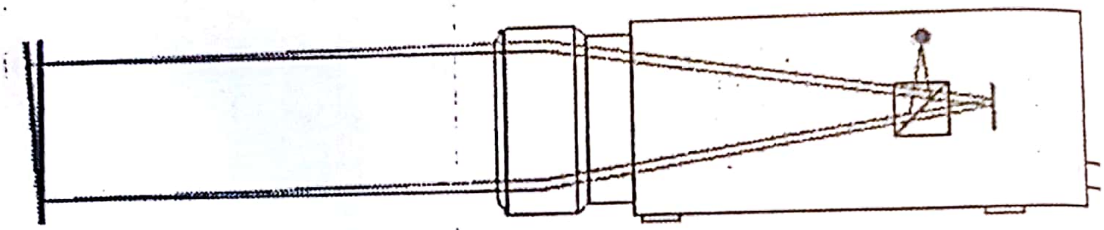
## ***THEORY:***

**Autocollimator:** is an optical instrument that is used to measure small angles with very high sensitivity.

## *Principles of operation of autocollimator:*

The autocollimator projects a beam of collimated "parallel" light. An external reflector reflects all or part of the beam back into the instrument where the beam is focused and detected by a photo detector.

The autocollimator measures the deviation between the emitted beam and the reflected beam. Because the autocollimator uses light to measure angles, it never comes into contact with the test surface.



- ● light source
- —— reflected beam when mirror is perpendicular to autocollimator
- —— reflected beam when mirror is tilted
- ▬ detecting surface

**Digital vs. Visual Autocollimators**

**Visual Autocollimators**

Visual autocollimators rely on the operator's eye to act as the photo detector. The operator views the reflected pinhole images through an eyepiece. Because the human eye acts as the photo detector, resolution will vary among operators. Typically, people can resolve from 3 to 5 arc-seconds.

**Digital Autocollimators**

Digital autocollimators use an electronic photo detector to detect the reflected beam. The detector sends a signal to a controller which digitizes and processes the signal using proprietary DSP-based electronics. The processing creates a calibrated angular output. The angular data is retrieved using a digital LCD display.

Applications:

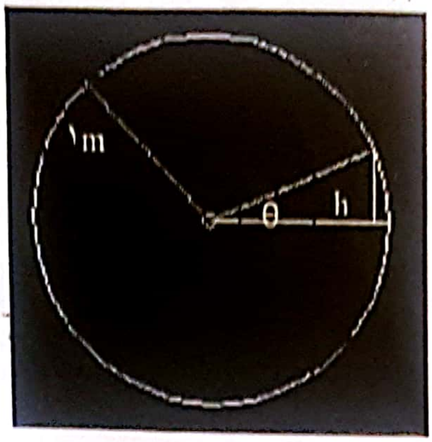
- Calibrating rotary tables.
- Checking angle standards.
- Remote or long term angular monitoring.
- Measurements of flatness or straightness.
- To provide angular feedback in servo-controlled systems.

## How to Calculate Tilt of 1 sec of Arc of the Reflector::

$\theta$ is the angle taken when after adjusting the micrometer properly (in seconds)

h is the vertical distance (to be found)

L is the length of the reflector Carriage which is 0.1m in our case.




Tanθ = h/ radius
θ = 1 sec of arc
h=tan 1 sec x Radius
h = 4.848 x $10^{-6}$ meter
h = 5 micrometer / meter approximately
h = 0.5 micrometer / $10^{-3}$ mm

$$\tan(\theta) = \frac{h}{l}$$

Assume $\theta = 1\,\text{sec}$

$\tan(\theta) \approx \theta$ for small values

$$1\,\text{sec} = \left(\frac{1}{60\times 60}\right)\frac{\pi}{180} = 4.8\times 10^{-6}\,rad$$

$$h = 4.8\times 10^{-6}\,m$$

i.e. each 1 sec indicates a vertical distance of approximately 0.5 micron "since L = 0.1m".

**ex:**
For θ=3° find the corresponding vertical distance, for L = 0.1m.

$$h = 3\times 60\times 60\times 4.8\times 10^{-7} = 5.18\times 10^{-3}\,m$$

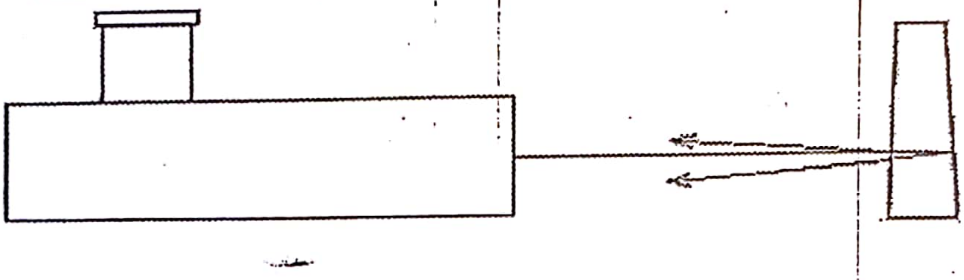
## Principles of operation

The autocollimator projects a beam of collimated light. An external reflector reflects all or part of the beam back into the instrument where the beam is focused and detected by a photodetector. The autocollimator measures the deviation between the emitted beam and the reflected beam. Because the autocollimator uses light to measure angles, it never comes into contact with the test surface.

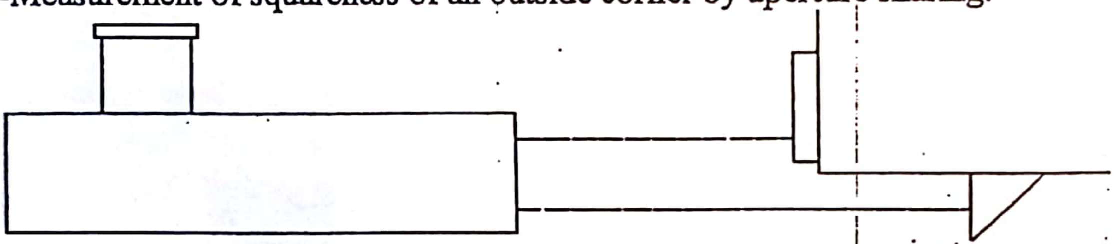
Visual autocollimators rely on the operator's eye to act as the photodetector. Micro-Radian visual autocollimators project a pinhole image. The operator views the reflected pinhole images through an eyepiece. Because the human eye acts as the photodetector, resolution will vary among operators. Typically, people can resolve from 3 to 5 arc-seconds. Because the human eye is able to discern mutiple images simultaneously, visual autocollimators are suitable for measuring multiple surfaces simultaneously. This makes them ideal alignment instruments in applications like aligning laser rod ends or checking parallelism among optics. Visual autocollimators can also be equipped with an eyepiece reticle for aid in lining up test optics to a master reference.

## Visual Autocollimator Sample Applications

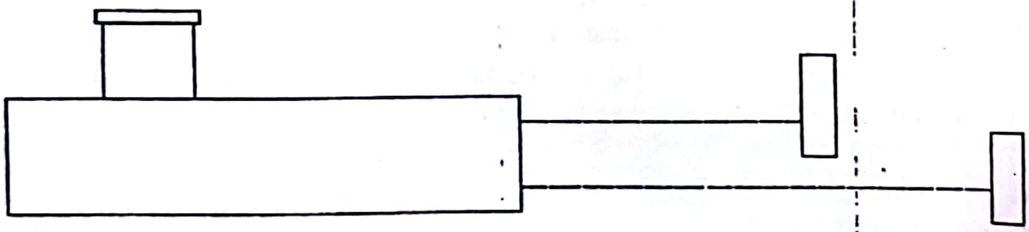
1-Measurement of non-parallelism in windows, laser rod ends,



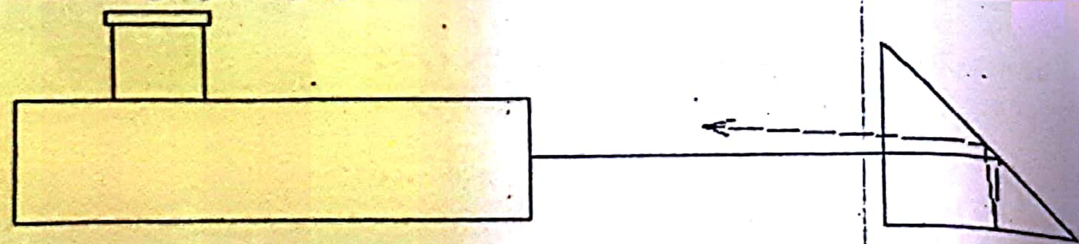
2-Measurement of squareness of an outside corner by aperture sharing.



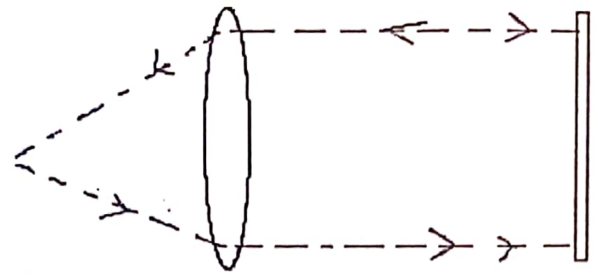
3- Angle comparisons by aperture sharing.



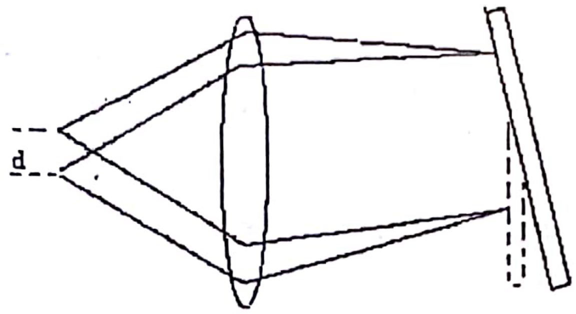
**4- Checking right angle prisms for angular and pyramid errors**



Reflected squares to beam



Reflection when reflector is square to the beam at light




A light beam is reflected due to the tilt angle of the reflector

## PROCEDURE

1. Clean the surface plate or table.

2. Position the auto-collimator in line with the reflector. Switch on the lamp in the autocollimator, the alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to make certain that the target graticule is contained within the eyepiece field.

3. Fix a guide strip to control the horizontal displacement of the reflector and minimise the movement of the target graticule.

4. Mark off the positions along the surface plate equal to the pitch positions on the reflector base (in this case 100 mm). Column 1 should indicate this position.

5. At the initial position takes the reading and tabulates (column 2)
6. Move the carriage (reflector) to the next position and again tabulate the reading.

7. This method is to continue until the final outward position is recorded.

To improve on the accuracy and ensure no errors have been introduced, readings should also be taken on the inward run. If this exercise is followed then the average of the two readings is to be shown in column 2.

8. The remainder of the table should be filled by adopting the following procedure:

- Column 3 This is the variations of the tilt occurring between the position at which the reading is taken and the original position.
- Column 4 The angular position in column 3 is converted into a linear measure (1 second = 0.5 micro m). Insert a zero at the top of the column to represent the datum.
- Column 5 This is the cumulative algebraic sum of the displacements. Calculate the mean displacement this is the amount by which the displacement must be adjusted to relate them to the zero datum.

Plot the values of column 5 versus column 1.

## Collected Data:

| | 1 | 2 | | 3 | 4. | 5 |
|---|---|---|---|---|---|---|
| Position | Position of Reflector Carriage | Auto-Collimator Readings | | Difference From First Reading | Vertical Rise OR Fall Over 100mm | Cumulative Rise Or Fall |
| | mm | Min. | Sec. | Sec. | Micrometer | Micrometer |
| 0 | 0 | - | - | - | - | 0 |
| 1 | 0-100 | | | | | |
| 2 | 100-200 | | | | | |
| 3 | 200-300 | | | | | |
| 4 | 300-400 | | | | | |
| 5 | 400-500 | | | | | |
| 6 | 500-600 | | | | | |
| 7 | 600-700 | | | | | |
| 8 | 700-800 | | | | | |
| 9 | 800-900 | | | | | |
| 10 | 900-1000 | | | | | |

*Notes on the table:*

- Column (1) this column shows the successive position of the reflector along the diagonal of the surface.
- Column (2) Auto collimator reading for each position is entered in this column.
- Column (3) gives the difference of each reading from the first one. This is required to establish a reference for our calculations.
- Column (4) the differences in column 3 are converted to the corresponding linear rise or fall.
- Column (5) obtained by adding together algebraically the values of column 4, which gives the height of the table at each position relative to the datum (reference) line.

## Discussion:

1. Determine the maximum straightness error with respect to:
   a. A line joining end points.
   b. The least square method line.
2. Draw the relation between the position and the autocollimator reading.
3. Find the position at which the reflection angle is zero, what do you suggests.
4. proof that the vertical distance (d) is equal to twice the reflection angle.
5. Discuss and compare your results.
6. Determine the source of error in the experiment.

## Review Questions:

»Explain the principle of the Auto-collimator.

» Are the existence of burrs or dust on the surface plate affect your result.

» Auto collimator works on the principle light reflection, it concerned with the idea that flat surface will reflect light at ------------ angle.

» The main scale is divided into --------- divisions each reads ------- min.

» The accuracy of the device is ----------

» The alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to --------------

University Of Jordan
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Industrial Engineering Department

# Measurement Lab.

**EXPERIMENT 4 :**

## SURFACE TEXTURE

**Student Name :**
**Student No. :**

**GROUP (        )**

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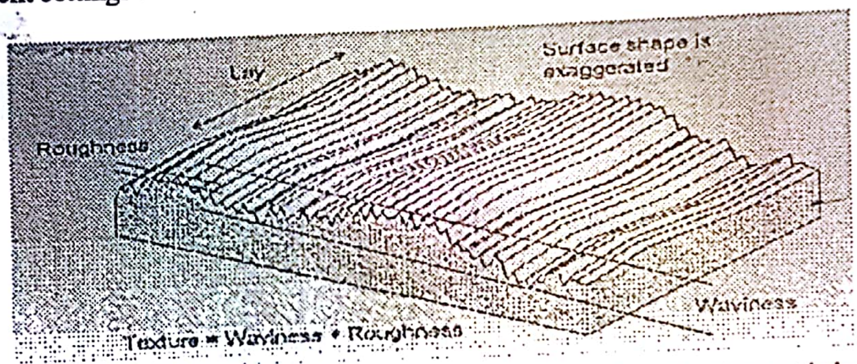
----------------------------------------
----------------------------------------
----------------------------------------

# SURFACE TEXTURE

***INTRODUCTION:**

Surface topography is of great importance in specifying the function of a surface. A significant proportion of component failure starts at the surface due to either an isolated manufacturing discontinuity or gradual deterioration of the surface quality. Typical of the former is the laps and folds which cause fatigue failures and of the latter is the grinding damage due to the use of a worn wheel resulting in stress corrosion and fatigue failure. The most important parameter describing surface integrity is surface roughness. In the manufacturing industry, surface must be within certain limits of roughness. Therefore, measuring surface roughness is vital to quality control of machining work piece. Below are the definition of surface roughness and its main measurement methods. . From a knowledge of the roughness amplitude and wavelength values expected from the surface, it is possible to select the appropriate instrument settings for a reliable roughness measurement.




Surface texture includes roughness and waviness. Many surfaces have lay: directional striations across the surface

**Fig.1**

***DEFINITIONS:**

In any discussion of this type, we need to start with a few definitions. The important ones here are:

**SURFACE TEXTURE** is the local deviations of a surface from its ideal shape e.g perfect flat shape, perfect cylinderical shape, sherical shape etc. The measure of the surface texture is generally determined in terms of its roughness, waviness and Form

** In surface texture there are many factors that, when combined, characterise a surface's profile. For example:

- the microstructure of the material
- the action of the cutting tool
- the instability of the cutting tool on the material
- errors in the machine tool guideways
- Mainly, what affects the surface texture could be summarized in the speed of the cutting tool, feed rate & the depth of cut.

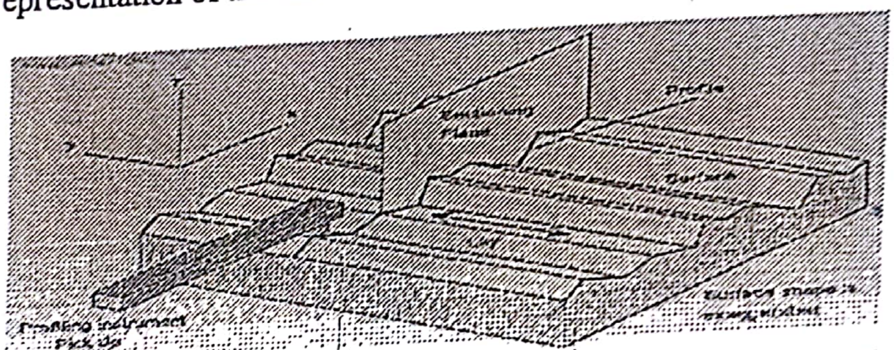
**ROUGHNESS** – a quantitative measure of the process marks produced during the creation of the surface and other factors such as the structure of the material. The action of the cutting tool, chemical action, polishing, lapping, and the structure of the material all contribute to the roughness of the surface.

**WAVINESS** – a longer wavelength variation in surface away from its basic form (e.g. straight line or arc). . It may result from such factors as machine or work deflection, vibration, chatter, heat treatment, or warping strains

**Because both process and machine induced irregularities occur simultaneously,roughness is superimposed over waviness.

**LAY** refers to the predominant direction of the surface texture. Ordinarily lay is determined by the particular production method and geometry used.Turning, milling, drilling, grinding, and other cutting tool machining processes usually produce a surface that has lay

**PROFILE** is, mathematically, the line of intersection of a surface with a sectioning plane which is (ordinarily) perpendicular to the surface. It is a two-dimensional slice of the three-dimensional surface. Almost always profiles are measured across the surface in a direction perpendicular to the lay of the surface. Shortly saying, it's the graphical representation of the surface.



**A profile is a two-dimensional picture of a three dimensional surface that may be thought of as the result of a sectioning place cutting the surface. Profiles are ordinarily taken perpendicular to the lay.**

**Fig.2**

**CENTER LINE** (Mean line) : mathematically it's poisoned in such a way that within the sampling length the sum of areas enclosed by the profile above & below the center line are equal.

**FORM** of a surface is the profile of the surface under consideration ignoring variations due to roughness and waviness. Deviations from the desired form result from clamping marks or sliding marks machining guide errors etc.

**Ra - Average Roughness**....The average roughness is the area between the roughness profile and its mean line, or the integral of the absolute value of the roughness profile height over the evaluation length Graphically, the average roughness is the area (shown below) between the roughness profile and its center line divided by the evaluation length (normally five sample lengths with each sample length equal to one evaluation length) This is the parameter that has been used universally for many years.

** $Ra = \sum A / L = \sum H / N$

Where A = Area between the center line & the profile.

L= Sampling length.

H = Height of a point chosen from the profile with respect to the center line.

N - number of heights taken

**FILTERS** are electronic or mathematical methods or algorithms which separate out different wavelengths and allow us to see only the wavelengths we are interested in.

**CUT-OFF** is a filter and is used as a means of separating or filtering the wavelengths of a component. Cut-offs have a numerical value that when selected will reduce or remove the unwanted wavelengths on the surface. For example, a roughness filter cut-off with a numeric value of 0.8mm will allow wavelengths below 0.8mm to be assessed with wavelengths above 0.8mm being reduced in amplitude; the greater the wavelength, the more severe the reduction. For a waviness filter cut-off with a numeric value of 0.8mm, wavelengths above 0.8mm will be assessed with wavelengths below 0.8mm being reduced in amplitude.

**SAMPLE LENGTH** : after the data has been filtered with a cut –off, we then sample it. Sampling is done by breaking the data into equal sample lengths. The sample lengths have the same numeric value as the cut-off. In other words, if you use a 0.8mm cut-off, then the filtered data will be broken down into 0.8mm sample lengths. These sample lengths are chosen in such a way that a good statistical analysis can be made of the surface. In most cases, five sample lengths are used for analysis.

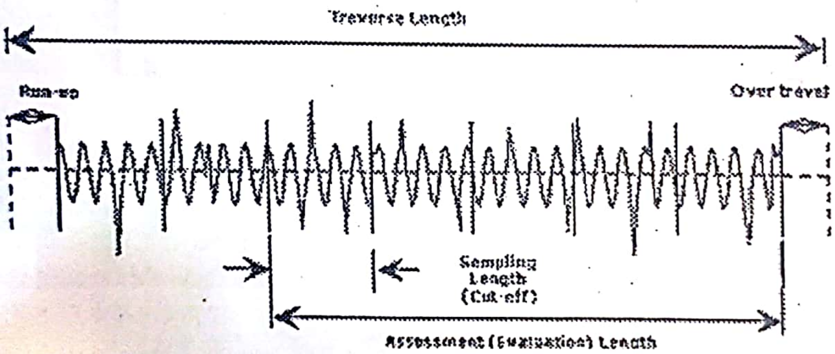



Fig.3

**Rsk** –(it's an amplitude parameter which's a measure of the vertical characteristics of the surface deviations).Rsk : is a measurement of skewness and will indicate whether the surface consists of mainly peaks, valleys or an equal combination of both. It is the measure of the symmetry of the profile about the mean line. A surface with predominant peaks will be considered as 'positive skew' and a surface with predominant valleys will be considered as 'negative skew'

**RSm (it's a spacing parameter– which's a measure of the horizontal characteristics of the surface deviations) Rsm : is the mean spacing between profile peaks as they pass through the mean line (spacing is the distance between points that cross the mean line within a sample length in an upward direction).**

***note - almost all parameters are defined over 1 sample length, however in practice more than 1 sample length is assessed (usually 5) and the mean calculated. This provides a better statistical estimate of the parameter's measured value**

## *PROCEDURE:

1- Tactile assessment : Which's a comparison of the surface roughness with a standard surface (Rubert gauges). The comparison is done by touching the surface with your fingernail & then comparing it with the gauges to establish the roughness value of the sample. Now, each gauge is specified for a certain process, i.e each gauge has a different color indicating a different process used in manufacturing the tested surface as milling, grinding, turning.. etc.
*Using rubert gauges, the estimated value of Ra = ............ micrometer.

2- The tracer method : Which uses a stylus that's dragged across the surface. This method is the most common for obtaining quantitative results.

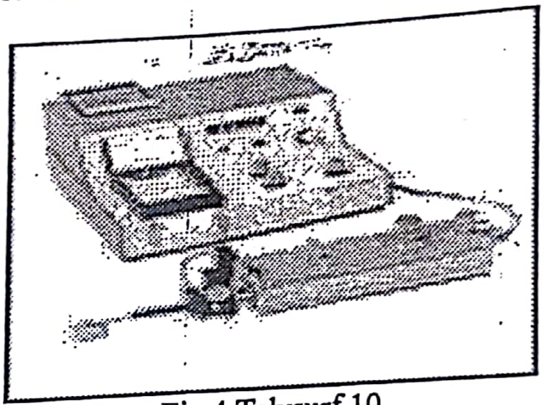


Fig.4 Talysurf 10

**Taylor-Hobson (Talysurf 10) Profilometer

This equipment measures surface profiles by scanning a mechanical stylus across the sample. The profilometer can be used to measure etch depths, deposited film thickness and surface roughness. A modern typical surface measuring instrument will consist of a stylus with a small tip (diamond) a gauge or transducer, a traverse datum and a processor. The surface is measured by moving the stylus across the surface. As the stylus moves up and down along the surface, the transducer converts this movement into a signal which is then exported to a processor which converts this into a number and usually a visual profile.(The stylus must be moved in a straight line to give accurate readings)

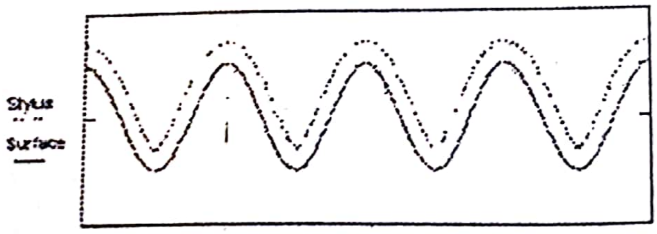



Figure1 - showing distortion due to finite stylus size.

•Below is a description of this process :

a- To record the profile of the specimen, switch on the instrument & adjust the coarse & fine adjustment found on the amplifier recorder to the mid position.

-The magnifications for both the vertical & horizontal are set to 1000 & 20 respectively.

- The specimen is placed in the V-block.

- Slowly bring the stylus on to the specimen until it touches the specimen. To make sure that there's a touching bring the stylus down more until the pen in the Graph Recorder comes to the mid position.
- For trial, take a trace by pressing the switch knob down.
- Now, run for a few centimeters & stop to adjust the vertical until the trace covers the graph paper.
- If you want the profile to be spread apart, switch the function knob to Vv same.

b- To find the roughness average, use the Ra meter.
- Hold the specimen on the V-block.
- Adjust the coarse & fine adjustment knobs to the mid position.
- Set the function knob Vv to the 0.8 mm cut-off length & Vv to 1000 magnification.
- Once again, slowly bring the stylus on to the specimen & check that it touches the specimen as previously.
-Press the start lever & take the reading from the Ra meter. To make use of the full range of the scale, choose the appropriate Vv & take another reading.

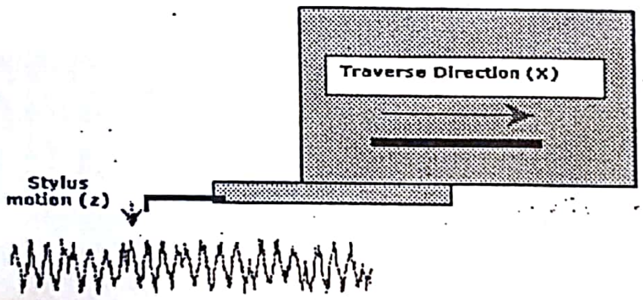



Fig.6

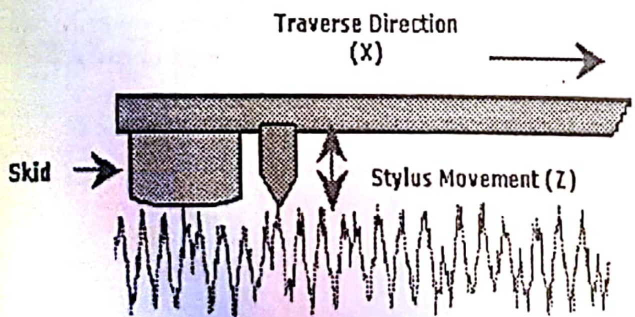



Fig.7

## *RESULTS:

Turning 1

| | Ra1 | Ra2 | Ra3 | average |
|---|---|---|---|---|
| Rubert gauge | | | | |
| Talysurf (direct) | | | | |
| Talysurf (calculated) | | | | |

Turning 2

| | Ra1 | Ra2 | Ra3 | average |
|---|---|---|---|---|
| Rubert gauge | | | | |
| Talysurf (direct) | | | | |
| Talysurf (calculated) | | | | |

Milling :

| | Ra1 | Ra2 | Ra3 | average |
|---|---|---|---|---|
| Rubert gauge | | | | |
| Talysurf (direct) | | | | |
| Talysurf (calculated) | | | | |

Grinding:

| | Ra1 | Ra2 | Ra3 | average |
|---|---|---|---|---|
| Rubert gauge | | | | |
| Talysurf (direct) | | | | |
| Talysurf (calculated) | | | | |

## *DISCUSSIONS:

1- What are the advantages & disadvantages of using Rubert gauges & the stylus.
2- Why do we need the profile of the component & is it a true picture of the surface?
3- What does 1 division on Ra scale represent when Vv= 50000 magnification.
4- How do we achieve the vertical & horizontal magnifications?
5- Why is the horizontal magnification limited to only a small value in comparison with the vertical one?
6- What do you think is more accurate in finding the Ra value, ( $\sum A / L$ ) or ( $\sum H / N$ ) ?
7- What does Ra represent graphically?

University Of Jordan
Faculty of Engineering and Technology
Mechanical Engineering Department

# Measurement Lab.

Experiment 5

# Screw Thread

**Student Name :**
**Student No. :**

***Screw thread***

## Objectives

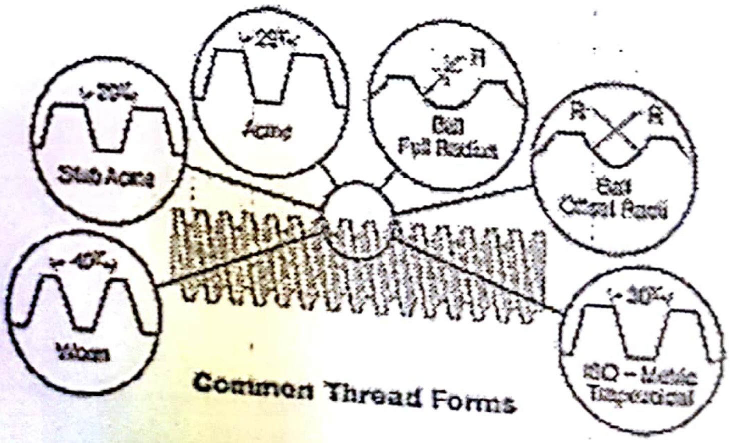
- Measure the major Diameter
- Measure the effective diameter
- Measure the minor diameter
- Learn how to use the pitch gauge
- To learn new important terms such as fiducial pointer, Vee prisms, and fiducial indicator

**APPARATUS:**
1. Floating carriage diameter measuring machine
2. Thread cylinders
3. Plain cylindrical standards
4. Vee prisms
5. Metric parallel screw thread plug gauge specimen

# Theory

## Thread Form

There are many different thread forms in use today. The forms most widely used for power transmission screw threads are illustrated in Figure 1. An optical comparator is the easiest method of determining thread form. Profile gages, if available, and visual methods can also be used. Great care must be taken as many forms are almost identical. The Acme form (29 degree included angle) is only 1 degree different from the ISO Metric Trapezoidal form (30 degree included angle). Many thread forms such as Unified, Metric ISO and Acme are subject to published standards while others, including Ball screw and Worm threads, are not defined in detail by any standards organizations.

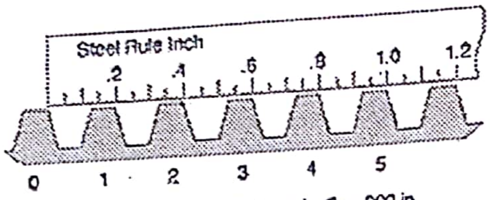



Common Thread Forms

## Thread Pitch

The thread pitch is the axial distance from one thread groove to the next its can be measured with a steel rule, as illustrated in figure below or a caliper or comparator can be used. By laying a steel rule down the axis of a screw and counting the number of thread crests in a given length, the pitch can be determined by dividing the count into the length.

**Example:** in the figure shown below. there are 5 pitches in 1 in. so the thread pitch is .200 in. Note that the number of threads per inch is the reciprocal of the thread pitch. A common mistake is to count the number of threads starting with "one". This will lead to a one pitch error. Make sure you start with "zero" for the first thread. To double check your pitch determination, check your pitch determined by count against your actual pitch measurement.




Pitch Count = 5. Pitch = 1 in./5 = .200 in.

## Hand of the Thread

The hand of the thread can be easily determined by visual inspection. Simply compare your screw threads with the right hand and left hand threads illustrated in figure below Most threads are right hand and right hand is assumed if no left hand designation is specified. Left hand threads are common on manual drives where clockwise handle rotation raises, tightens, extends, or creates motion away from the operator. On fine threads, it may be necessary to lay a small wire in the thread grooves to determine hand. Matching the angle of lie of the wire with the illustrations will indicate the hand of thread.

Right Hand Thread Left Hand Thread

## The pitch diameter (often called the effective diameter)

The pitch diameter is the diameter at which the thread tooth and the thread space are equal.

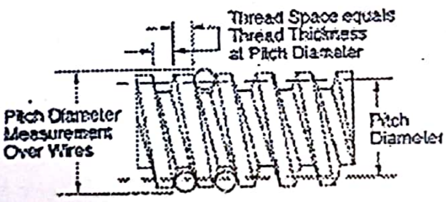



Figure : Pitch diameter

**The major diameter** : can be measured with a micrometer, caliper or steel rule

Care must be taken to measure the major diameter on a section of the screw thread that is not worn. A worn portion will measure smaller (or larger if burrs have been rolled up) than the original major diameter

Therefore, it is good practice to measure the major diameter over the least used section of the screw.

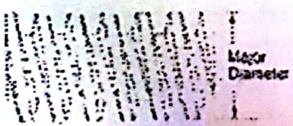



Figure (3): Major Diameter

The minor diameter is the diameter of the cylinder that just touches the root of an internal thread.

**The minor diameter can be determined by measuring the depth of the thread with a depth micrometer and subtracting twice the measured depth of thread from the major diameter. When using a comparator to measure the minor diameter,**

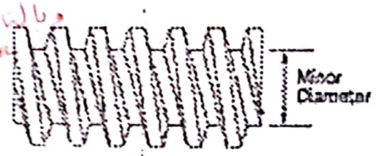


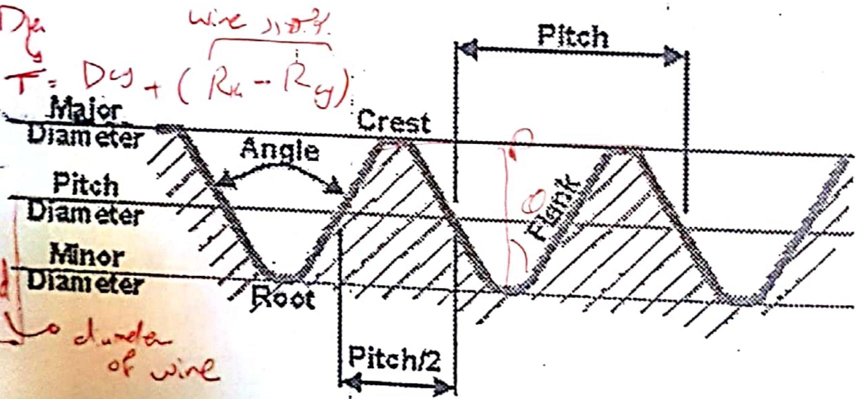

Figure (4): Minor diameter

The crest of a thread : is the prominent part of a thread, whether internal or external.

The root : is the bottom of the groove between the two flanking surfaces of the thread whether internal or external.

The flanks of a thread: are the straight sides that connect the crest and the root.

The angle of a thread : is the angle between the flanks, measured in an axial plane section.




## Measuremenrt of major diameter:

**Select the appropriate cylindrical standard and mount it between the two male centers. Take the reading R of the micrometer when the fiducial pointer in the null position. The standard is then replaced by the workpiece; the specimen provided and a second reading $R_g$ is taken.**

**If the micrometer reading over cylindrical standard= R mm** → the micrometer **reading over specimen= $R_g$ mm,** the diameter of the cylindrical styandard= D mm **Then major diameter= D+ ($R_g$ –R)**

## Measurement of mean effective diameter:

1. **We selected per correct thread measuring cylinders (wires) from the tables. Again we mounted the plan cylindrical standard between the two centers. We hanged the thread measuring cylindrical vertically, freely from the hook and we took the micrometer reading say $R_s$.**

2. The standard is then replaced by the specimen with the thread measuring cylinders located in the thread form. A second reading $R_g$ of the micrometer is taken.

The value p is the difference between the effective diameter (E) and the diameter under the cylinder (T) as below. (i.e. P=E-T).
the value of P is usually calculated from the following expression:
$P=6/2\cot\theta-(\csc\theta-1)d$

If θ=30 then P=0.86602*Pitch-diameter of thread measuring cylinders (wires).
Now the reading for an effective diameter equal the standard diameter=$R_s$-P value
If E is the actual effective diameter of the specimen, then E=D±[($R_s$-P value)-$R_g$] mm

## Measurement of the minor diameter:

To determine the minor diameter of a thread, measurement are taken over prisms. We selected the appropriate size prisms from the table.
The first reading is taken over a cylindrical standard and selected Vee prisms, and we measured $R_s$.
Having taken the reading, the standard is replaced by the specimen with prisms located in the thread root. A second reading "$R_g$" of the micrometer is taken.
If: Reading over standard and prisms = $R_s$, Reading over work piece and prisms = $R_g$
Diameter of the standard= D
Then the minor diameter $C=D\pm(R_s-R_g)$ mm

# CALCULATIONS

1. by using a **micrometer** or caliper; determine the major diameter (actual outside diameter) of the male screw thread.

2. by using a **rule or caliper**, determine the number of threads per inch. (see diagram ii).

3. measure very carefully the pitch (p) using a thread pitch gage, or any other type of measuring tool which will give an accurate reading for pitch.

4. multiply the factor value: (f)=1.0825 by the pitch (p) which yields result (r). f x p = r. example: 1.0825 (f) x 1.75 (p) = 1.8944 (r)

5. measure very carefully the (i.d.) inside diameter (**minor diameter**) of the female metric thread using an internal micrometer, internal caliper, or gage pin.

4. add the measured value for the inside diameter (i.d.) to the result (r) which will yield the nominal major diameter (o.d.) of the female thread. i.d. + r = o.d. example: assume measured value 10.1036 (i.d.) + 1.8944 (r) = 12 (o.d. or approximate nominal major diameter).

3 Scales
0.5/50 = 0.01
0.5/250 = 0.002
0.002/10 = 0.0002

5. fill the following table:

| Parameters | BS3643 Size | Measured size | Comments, Satisfactory/unsatisfactory |
|---|---|---|---|
| Major Diameter | 30.00+0.002 to +0.030 | | |
| Minor Diameter | 26.12 | | |
| Simple effective Diameter | 27.727+0.009 to 0.023 | | |
| Pitch | 3.5 mm+0.006 | | |
| Flank angle | 30° 0' +9' | | |

**Review questions**

1-What is the main features of screw thread ?
2-Define the following terms :crest,root,pitch,pitch diameter?
3-What is the difference between major and minor diameter?

## Discussion and conclusion :

- Why we are taken comparative measurement
- The designed accuracy of the floating carriage micrometer is mm
- What are the advantages of fiducial & non rotating micrometer spindle?

University Of Jordan
Faculty of Engineering and Technology
Industrial Engineering Department

# Measurement Lab.

EXPERIMENT 5 :

## SINE BAR & ANGULAR MEASURMENTS

**Student Name :**
**Student No. :**

**GROUP (      )**

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# SINE BAR & ANGULAR MEASURMENTS

***OBJECTIVES:***

To familiarize student with the use of bevel protractor, vernier protractor, clinometer and sine bar for measuring angles.

***APPARATUS:***

1) Plain bevel protractor.
2) Vernier protractor.
3) Clinometer.
4) Sine bar.
5) Block gauges.
6) Specimen A & B.
7) Granite plate.

Protraction

***THEORY:***

***Bevel Protractor:***

When two surfaces are at any angle other than 90°, the angle between them must be tested with some form of protractor. Instruments for this purpose may have a scale of degrees, enabling the angle to be read off, or they may consists of gauge which must be set to the angle before use. And the Bevel Protractor fig. (1) is an example of this second variety of gauges, and must be set to the correct angle before use.

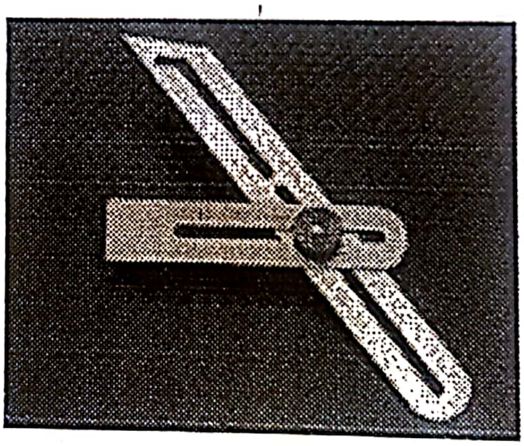


Fig. (1) bevel protractor

(1) ***The Plain Bevel Protractor:***

Consists mainly from main scale, movable arm and fixed nut, see fig(2). Its main scale is divided into 180 division, each division equals 1°, thus accuracy =±0.5° and total revolution can be measured = 180°.

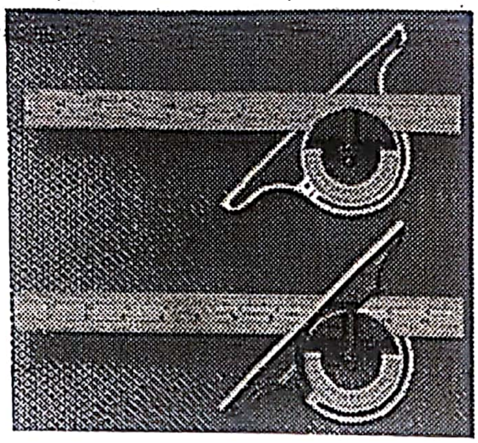
low resolution device

180°

Acc = ±0.5°

0.5°

±0.5°



NOTE: °=degree, '= minute.

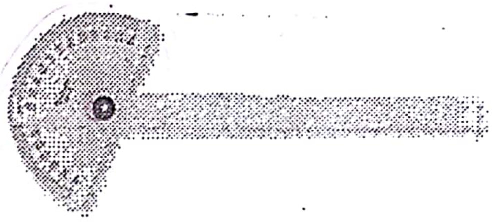


Fig. (2) Plain bevel protractor

## 2) *Vernier Protractor:*

The main scale of this device is divided up into degrees from 0 to 90° each way. The vernier scale is divided up to that 12 of its division occupying the same space as 23° on the main scale, thus 1 vernier division =23/12= 1.92 degree on main scale. The instrument therefore allows settings to 5 min of angle to be obtained, so we use it to get accurate readings. This device has a movable arm, plate blade, fixed nut and vernier scale, see fig. (3).

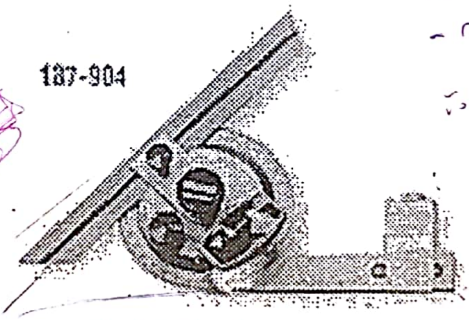



Fig. (3) Vernier protractor

*Reading the vernier protractor:*

1- Read of directly from the scale the number of whole degrees between 0 on the main scale and 0 on the vernier scale.
2- Count in the same direction the number of divisions from the 0 on the vernier scale to the first line on it that is level with a line on the main scale. As each division on the vernier scale represents 5', the number of these divisions multiplied by 5 will be the number of minutes to be added to the whole number of degrees. Actually the multiplication is not necessary, as it has been done on the scale. In fig. (4) notice that the number of the whole degrees is 85 degrees, and the mark on the vernier representing 30 minutes is level. The reading is therefore 85° 30'.

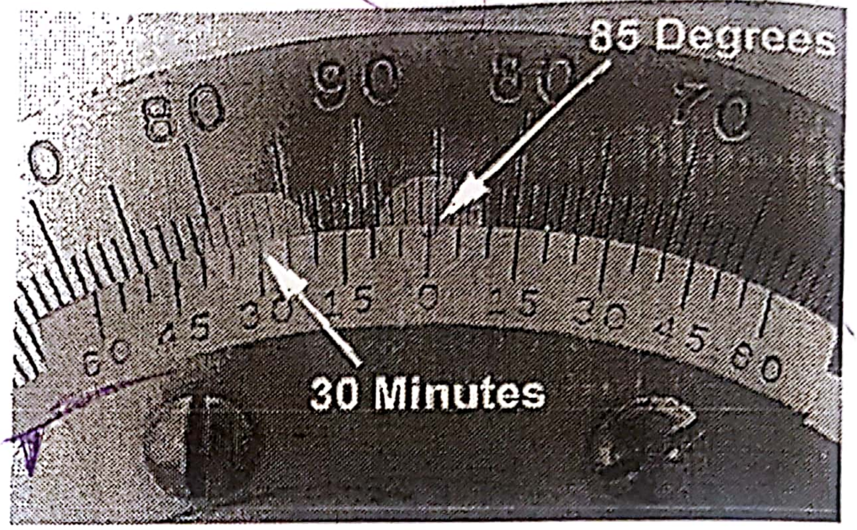



Fig. (4): Always read the vernier in the same direction that you read the dial.

## -The Clinometer:

The clinometer is a special case of the application of the spirit level. In this instance the level is mounted in a ratable body carried in a housing, one face of which forms the base of the instrument. A main use of the instrument is the measurement of the included angle of two adjacent faces of a work piece. Thus, in use, the instrument base is placed on one face and rot.table body is adjusted until a zero reading of the bubble is obtained. The angle of rotation necessary to bring this about is then shown on an angular scale moving against an index.

A second reading is taken in a similar manner on the second face of the work piece, the included angle between the faces being the difference the first and the second readings. Depending upon the type of instrument used, reading direct to 1 min are obtained, and up to range of movement of 90°, see fig. (5).

Main Scale =360°.

Vernier scale: full revolution= 1° = 60 min, so each division on vernier scale = 1 min.

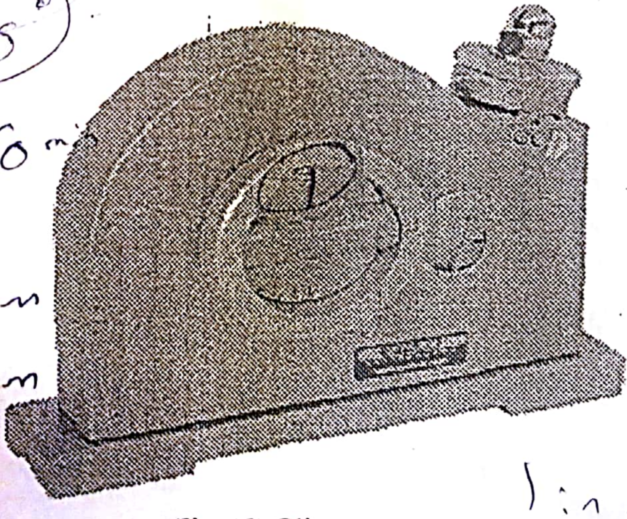


Fig. (5) Clinometer

*Reading the clinometer:*

1- Measure the angle γ of the component provided with the plate and the vernier protractors. Enter the values in table.

2- To measure the angle γ of the component with the clinometers:

   a. Place the component on the table and mark it around.

   b. But the clinometer on to of the component and the same axis, of the specimen.

3- To determine the inclination of the clinometer, the bubble unit is leveled by releasing the worm and turning the degrees graduated wheel:

   a. Finer adjustment is made with the knurled micrometer knob.

   b. Note the readings in degrees and minutes.

   c. Take second reading by keeping the clinometer in the same direction but reverse the component.

***Sine Bar:***

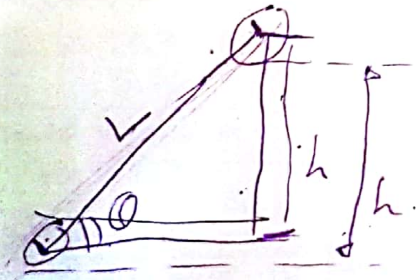
The bar is essentially a hardened steel beam mounted on two hardened cylinders. The high degree of accuracy and precision available for length measurement in the form of gauges blocks may be utilized for angle measurements. The center distance between the two cylinders = 200 mm. Hence, if the difference in height of the cylinder can be accurately measured, possibly with gauge block stack, a right angle triangle is available from which an applied rate value of the angle can be calculated, using the Trigonometrically ratio.

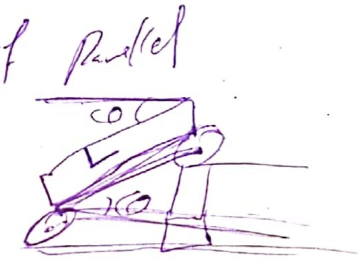
Thus, when θ = angle to be measured then

$$\sin\theta = \frac{side\_opposite\_the\_angle}{Hypotenuse}$$

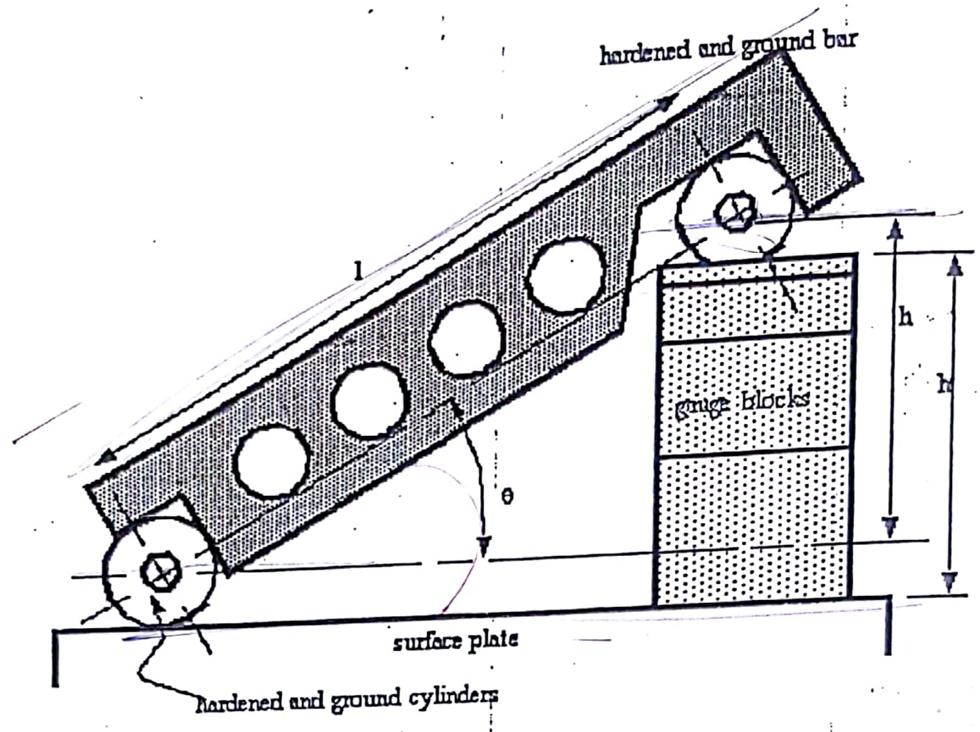
See fig.(6), you can see that sinθ= h/l $\sin\theta = \frac{h}{L}$

So, probable error = dθ $= \pm\left(\frac{dH}{H}+\frac{dL}{L}\right)\tan\theta$





$\theta = \sin^{-1}\left(\frac{h}{L}\right)$




l = distance between centres of ground cylinders (typically 5" or 10")
h = height of the gauge blocks
θ = the angle of the plate

$$\theta' = \operatorname{asin}\left(\frac{h}{l}\right)$$

Fig. (6) Sine bar

Gauge blocks can provide lengths only in small steps and it may not possible to build a gauge pile to the exact height required for a given angle and we use a dial indicator to make sure that we are at the exact height. The error is small but its magnitude depends on the step change of gauge block set.

To insure that the compound angle error is not introduced, the axis of the work must always be parallel to the axis of the sine bar.

## *PROCEDURE:*

First of all clean the component and remove the burrs if there is any, also make sure that the surface plate is nice and clean. In order to avoid compound angle error care must be taken in aligning the work piece with the sine bar axis.

Set-up the sine bar and work piece as shown up in fig. (6), so that the upper surface of the work piece is approximately parallel with the table surface. Take the series of readings along its upper surface with the dial gauge. The readings are not constant, increase or decrease the gauge block height until the DTI has same readings at both ends.

Finally add the gauge block increments to work out the value of h..

## *CALCULATIONS:*

Calculate the probable error that can occur in measuring the angle with following individual errors.

e.g. Accumulated gauge block error from calibration certificate +0.00001 mm.
Sine bar cylinders center distance error –0.00005 mm.

## DISCUSSION:

Discuss the personal skills required, overall time taken in measurement and suggest whether you would use the sine bar for one component or on a production line.

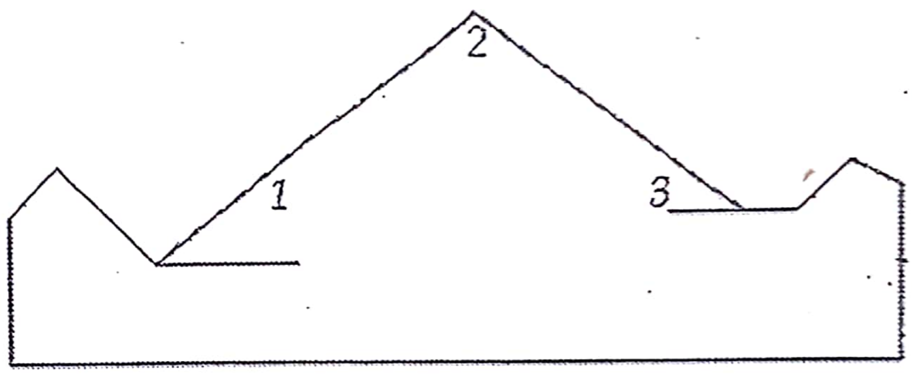



Fig. (7) The specimen

## RESULTS:

Speciment (5)

| Equipment used | Angle 3 | | | Angle 2 | | | Angle 1 | | | Accuracy | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | deg | min | sec | deg | min | sec | deg | min | sec | min | sec |
| Plate Protractor | 48 | | | 106 | | | cant | | | | |
| Vernier Protractor | 50 | 0 | | 104 | 55 | | 27° | 30 | | | |
| Clinometer | 48 | 26 | | | | | 27 | 37 | | | |
| Sine Bar | | | | | | | | | | | |

# The Resistance Temperature Detector (RTD) Characteristics

## Objectives:

1. To know what is an RTD.
2. To know how to convert the RTD resistance reading to temperature.
3. To understand the characteristics of the RTD.

## Introduction:

**RTDs or Resistance Temperature Detectors,** are electrical resistors that change resistance as temperature changes, with all common types of RTD, the resistance increases as temperature increases, this is referred to as Positive Temperature coefficient PTC.

RTD's are manufactured using several different materials as the sensing element. The most common by far is the Platinum RTD. Platinum is used for several different reasons including high temperature rating, very stable, and very repeatable. Other materials used to make RTD's are nickel, copper, and nickel-iron. These materials are becoming less common now, because the cost of platinum RTD's is coming down.

RTDs are constructed using one of two different manufacturing configurations. Wire-wound RTDs are created by winding a thin wire into a coil. A more common configuration is the thin-film element, which consists of a very thin layer of metal laid out on a plastic or ceramic substrate. Thin-film elements are cheaper and more widely available because they can achieve higher nominal resistances with less platinum. To protect the RTD, a metal sheath encloses the RTD element and the lead wires connected to it.

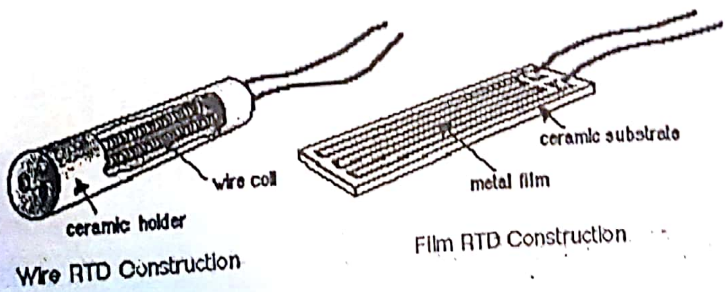



Figure (1): RTD Constructions

They are popular because of their stability; RTDs exhibit the most linear signal with respect to temperature of any electronic temperature sensor. However, they are generally more expensive than alternatives because of the careful construction and use of platinum. RTDs are also characterized by a slow response time and low sensitivity, and, because they require current excitation, they can be prone to self-heating.

## *Theory:*

RTDs are commonly categorized by their nominal resistance at 0 °C. Typical nominal resistance values for platinum thin-film RTDs include 100 and 1000 Ω. In TMT a **PT100 RTD** is used.

In order to measure temperature with the RTD, you only need to measure the resistance of the RTD, and then substitute the resistance value in the following equation

$$T = \frac{R_o - R}{-0.5(R_o A + \sqrt{R_o^2 A^2 - 4R_o B(R_o - R)})}$$

*Where :*

*T : Calculated temperature in (°C).*
*$R_o$ : RTD nominal resistance at 0 °C, $R_o$=100 Ω.*
*R : Measured resistance (Ω).*
*$A = 3.90802\times10^{-3}$*
*$B = -5.80195\times10^{-7}$*

The above equation will give you the temperature in °C. The value of $R_o$, A & B differs from one type of RTD to another.

## *Experiment Procedure:*

1. Refer to running procedure in Thermocouple Experiment.
2. Choose Experiment 2: "**RTD Characteristics**".

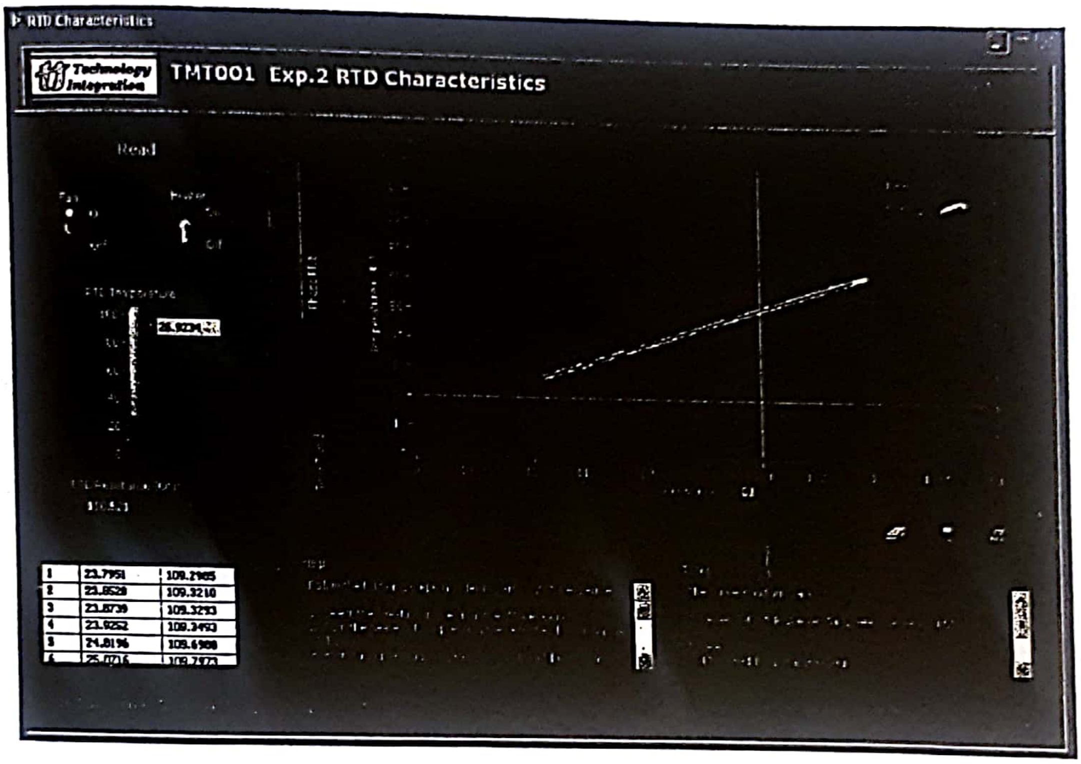



Figure (2): RTD Characteristics Experiment.

3. Study the front panel carefully and observe the buttons on the screen.
4. Turn the Heater ON by pressing ON the **Heater Switch** on the screen (Heating Mode).
5. Start taking readings by pressing **[Read]** button over different temperature values.
6. The acquired readings appear on the Temperature-Resistance graph as red points.
7. Compare the read temperature with the temperature of the **glass thermometer.** Is it the same temperature? Why?

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8. Turn the **Heater** OFF by pressing OFF the **Heater Switch** on the screen.
9. Turn the **Fan** ON by pressing ON the **Fan Switch** on the screen (Cooling Mode).
10. Start taking readings by pressing **[Read]** button on different temperature values.
11. The acquired reading appears on the Temperature-Resistance graph as white points.
12. Is the cooling curve the same as the heating curve? Why?
    ..............................................................................................................
    ..............................................................................................................
    ..............................................................................................................
13. Notice the Temperature vs. Resistance curve and answer the following questions:

14. 1 Is the curve linear?
    a) Yes
    b) No

14. 2 Does the RTD equation in the "**Theory**" window describe the curve on the Temperature-Resistance graph? If your answer is "No", what is the difference and why?
    ..............................................................................................................
    ..............................................................................................................
    ..............................................................................................................

15. Choose one of the readings taken before from the **Readings Table** and write down its Resistance (Ω) and Temperature (°C) readings:

    15. 1 Current Resistance (Ω) ............................
    15. 2 Current temperature (°C)........................
    15. 3 Apply the current resistance in the RTD equation
    15. 4 Write down the Calculated temperature (°C).....................
    15.5 Compare the calculated temperature with the current temperature.

## *Conclusions*

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# *Thermistor characteristics*

Temp, Res

## *Objectives:*

1. To know what is a **Thermistor.**
2. To know how to convert the Thermistor resistance reading to temperature.
3. To understand the characteristics of the Thermistor.

## *Introduction:*

Thermistors, like RTDs, are thermally sensitive semiconductors whose resistance varies with temperature. Thermistors are manufactured from metal oxide semiconductor material encapsulated in a glass or epoxy bead. Also, thermistors typically have much higher nominal resistance values than RTDs (anywhere from 2,000 to 10,000 Ω) and can be used for lower currents.

Each sensor has a designated nominal resistance that varies proportionally with temperature according to a linearized approximation. Thermistors have either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC). The first, more common, has a resistance that decreases with increasing temperature while the latter exhibits increased resistance with increasing temperature.

Thermistors typically have a very high sensitivity (~200 Ω/°C), making them extremely responsive to changes in temperature. Though they exhibit a fast response rate, thermistors are limited for use up to the 300 °C temperature range. This, along with their high nominal resistance, helps to provide precise measurements in lower-temperature applications. In TMT001 we use an NTC thermistor which has a temperature range from 13-85 °C.

## *Theory:*

In order to measure temperature with the thermistor,. you only need to measure the resistance of the thermistor, and then substitute the resistance value in the following equation

$$T = \frac{1}{a + b(lnR) + c(lnR)^3}$$

*Where :*

*T : Calculated temperature in (K)*
*R: Measured resistance in (Ω)*
*a, b and c are Steinhart-Hart Constants that have the following values*
$a = 1.2407635*10^{-3}$
$b = 2.3612017*10^{-4}$
$c = 8.97975*10^{-8}$

From the above equation you will get the temperature in Kelvin. The value of a, b and c differs from one type of to another.

## *Experiment Procedure:*

1. Refer to running procedure in Thermocouple Experiment.
2. Choose Experiment 3: "**Thermistor Characteristics**".

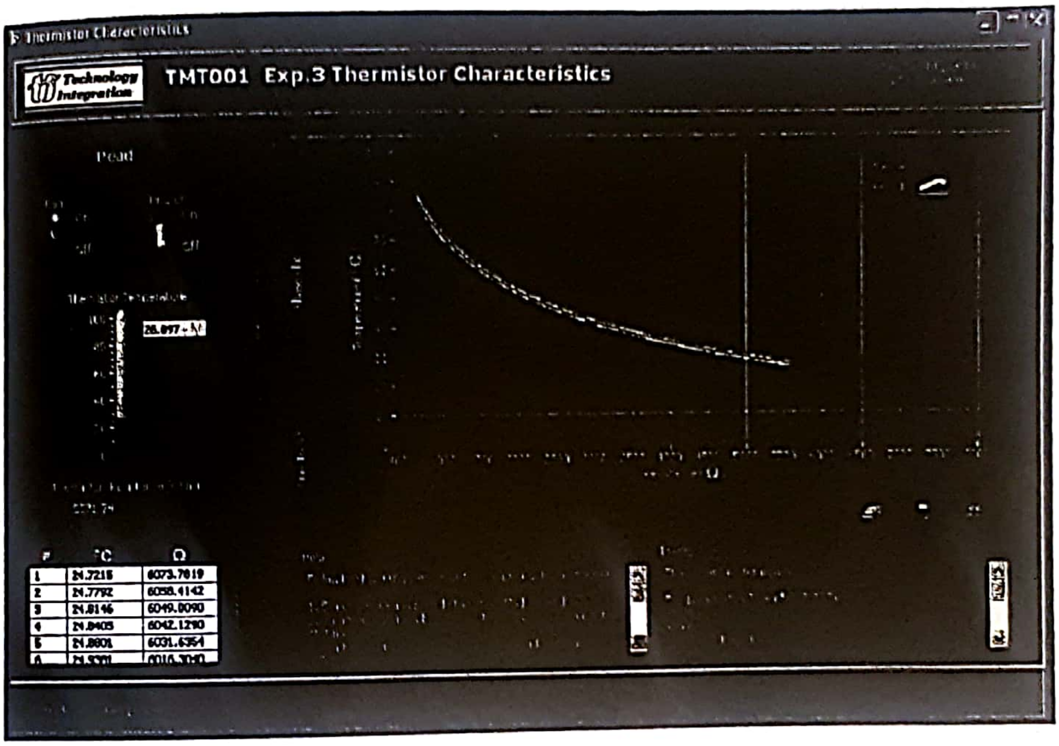


Figure (1): Thermistor Characteristics Experiment

3. Study the front panel carefully and observe the buttons on the screen.
4. Turn the **Heater** ON by pressing ON the **Heater Switch** on the screen (Heating Mode).
5. Start taking readings by pressing [Read] button over different temperature values.
6. The acquired readings appear on the Temperature-Resistance graph as red points.
7. Compare the read temperature with the temperature of the glass thermometer. Is it the same temperature? Why?
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8. Turn the **Heater** OFF by pressing OFF the **Heater Switch** on the screen.
9. Turn the **Fan** ON by pressing ON the Fan Switch on the screen (Cooling Mode).

10. Start taking readings by pressing **[Read]** button on different temperature values.

11. The acquired reading appears on the Temperature-Resistance graph as white points.

12. Is the cooling curve the same as the heating curve? Why? ....................
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13. Notice the Temperature vs. Resistance curve and answer the following questions:

14. 1 Is the curve linear?
 a) Yes
 b) No

14. 2 Does the Thermistor equation in the **"Theory"** window describe the curve on the Temperature-Resistance graph? If your answer is "No", what is the difference and why?
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15. Choose one of the readings taken before from the **Readings Table** and write down its Resistance (Ω) and Temperature (°C) readings:

 15. 1 Current Resistance (Ω) ............................
 15. 2 Current temperature (°C)........................
 15. 3 Apply the current resistance in the Thermistor equation
 15. 4 Write down the Calculated temperature (°C)......................
 15.5 Compare the calculated temperature with the current temperature.

## *Conclusions*

1. ..........................................................................................
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# *Thermometers Comparison*

## *Introduction:*

As mentioned before, temperature is one of the most important phenomena that needed to be measured in real life applications; consequently there are more than 20 different types of thermometers these days. These thermometers have different specifications, such as measuring method, temperature range, linearity, stability, repeatability, accuracy and response time…etc.

Thermocouples, RTDs and Thermistors, are the most common thermometers in real life applications. Engineer chooses the suitable thermometer according to the specification of the application. In this experiment, you will be able to compare the behavior and the characteristics of these thermometers.

## *Experiment Procedure:*

1. Refer to running procedure in Thermocouple Experiment.
2. Choose Experiment 4:" **Thermometers Comparison**".

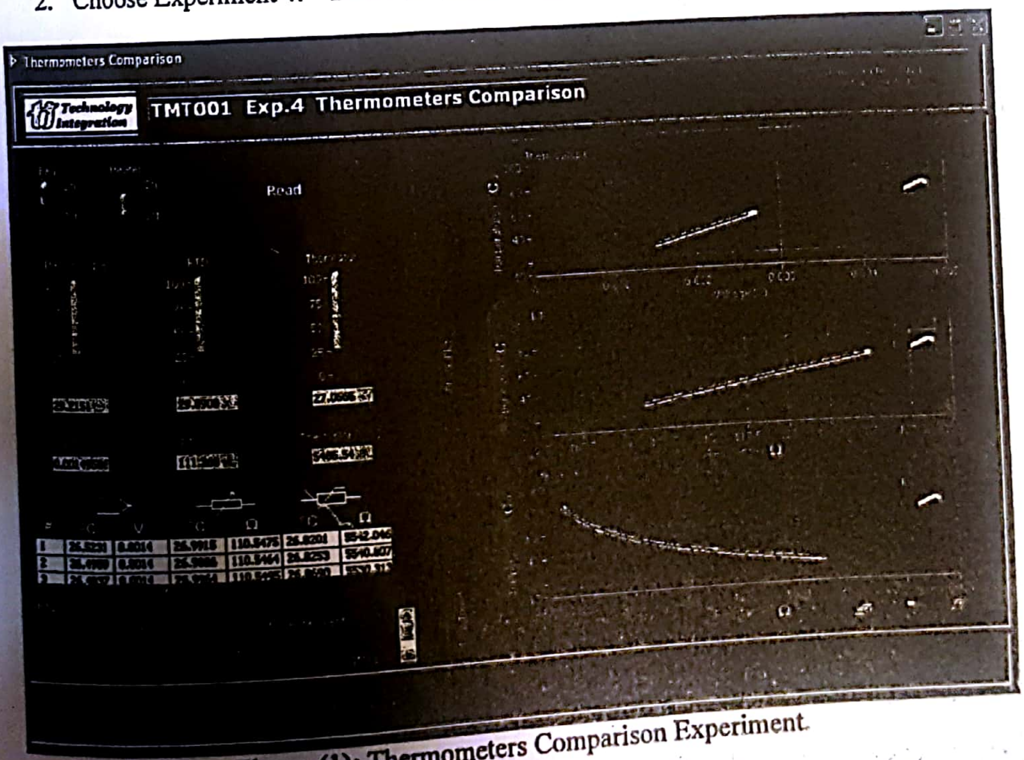


**Figure (1): Thermometers Comparison Experiment.**

3. Study the front panel carefully and observe the buttons on the screen.
4. Turn the **Heater** ON by pressing ON the **Heater Switch** on the screen (Heating Mode).
5. Start taking readings by pressing **[Read]** button over different temperature values.
6. The acquired readings appear on the Temperature-Resistance graph as red points.
7. Compare the read temperature values with the temperature of the glass thermometer.
8. Which thermometer has the closest readings compared to the glass thermometer readings:

   a) Thermocouple
   b) RTD
   c) Thermistor

9. Turn the **Heater** OFF by pressing OFF the **Heater Switch** on the screen.
10. Turn the **Fan** ON by pressing ON the **Fan Switch** on the screen (Cooling Mode).
11. Start taking readings by pressing [Read] button on different temperature values.
12. The acquired readings appear on the Temperature-Voltage (or Resistance) graph as white points.
13. Are the cooling curves of the thermometers the same as the heating curves? Why?

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..........................................................................................

14. Notice the Temperature-Voltage (or Resistance) curves and the Temperature-Time curves (on the Trends tab) and answer the following questions:

14.1 Which one of the thermometers has the fastest response time?

a) Thermocouple
b) RTD
c) Thermistor

14.2 Which one of the thermometers has the slowest response time?

a) Thermocouple
b) RTD
c) Thermistor

# *Thermocouple Characteristics*

## *Objectives:*

1. To know what is a **Thermocouple.**
2. To know how to convert the thermocouple voltage readings to temperature.
3. To understand the characteristics of the thermocouple.

## *Introduction:*

Thermocouple (TC) is created whenever two dissimilar metals touch and the contact point produces a small open-circuit voltage as a function of temperature. This thermoelectric voltage is known as the Seebeck voltage, named after Thomas Seebeck, who discovered it in 1821.

The TC has been the popular choice over the years for a variety of reasons. Thermocouples are relatively inexpensive and can be produced in a variety of sizes and shapes. They can be of rugged construction, can cover a wide temperature range. However, TCs produce a very small microvolt output per degree change in temperature that is very sensitive to environmental influences.

As Mentioned above any two dissimilar metals may produce a TC, However, there are some standard thermocouples which have calibration tables and assigned letter-designations which are recognized worldwide, Such as, J-type (Iron / Constantan), K-type (Chromel / Alumel), E-type (Chromel / Constantan), N-type (Nicrosil / Nisil), B-type (Platinum / Rhodium), R-type (Platinum / Rhodium) and S-type (Platinum / Rhodium). In order to select the suitable TC for an application, sensitivity and temperature range should be taken into consideration, because each one of these thermocouples has different temperature range and sensitivity.

In the experiment two J type thermocouples are used. The first one is used for the experiments, and the other one is used with temperature controller to control the temperature of the hot plate.

## *Theory:*

To measure a thermocouple Seebeck voltage, you cannot simply connect the thermocouple to a voltmeter or other measurement system, because connecting the thermocouple wires to the measurement system creates additional thermoelectric circuits.

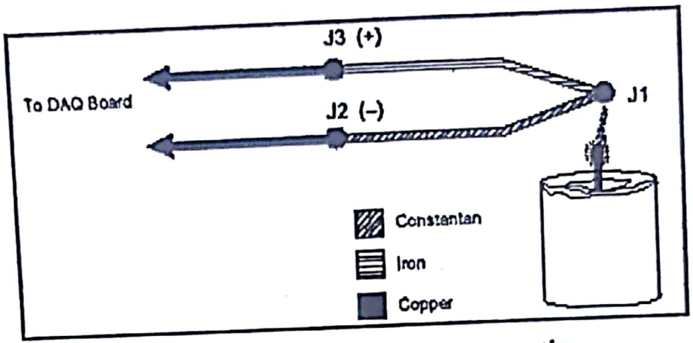


Figure (1): Thermocouple connection

Consider the circuit illustrated in Figure 1, in which a J-type thermocouple is in a candle flame that has a temperature you want to measure. The two thermocouple wires are connected to the copper leads of the measurement device. Notice that the circuit contains three dissimilar metal junctions J1, J2, and J3. J1, the thermocouple junction, generates a Seebeck voltage proportional to the temperature of the candle flame. J2 and J3 each have their own Seebeck coefficient and generate their own thermoelectric voltage proportional to the temperature at the measurement device terminals. To determine the voltage contribution from J1, you need to know the temperatures of junctions J2 and J3 as well as the voltage-to-temperature relationships for these junctions. You can then subtract the contributions of the parasitic junctions at J2 and J3 from the measured voltage at junction J1.

Thermocouples require some form of temperature reference to compensate for these unwanted parasitic "cold" junctions. The most common method is to measure the temperature at the reference junction with a direct-reading temperature sensor and subtract the parasitic junction voltage contributions. This process is called **cold-junction compensation.** You can simplify computing cold-junction compensation by taking advantage of some thermocouple characteristics.

By using the **Thermocouple Law of Intermediate Metals** and making some simple assumptions, you can see that the voltage a data acquisition system measures depends only on the thermocouple type, the thermocouple voltage, and the cold-junction temperature. The measured voltage is in fact independent of the composition of the measurement leads and the cold junctions, J2 and J3.

According to the Thermocouple Law of Intermediate Metals, illustrated in Figure 2, inserting any type of wire into a thermocouple circuit has no effect on the output as long as both ends of that wire are the same temperature, or isothermal.

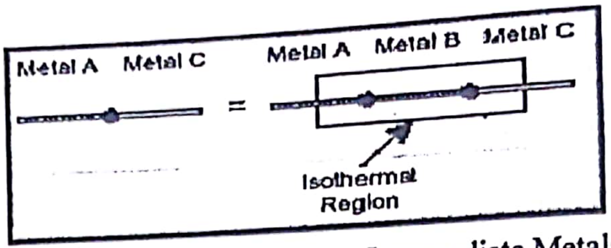


Figure (2): Thermocouple Law Intermediate Metals.

Consider the circuit in Figure 3. This circuit is similar to the previously described circuit in Figure 1, but a short length of constantan wire has been inserted just before junction J3 and the junctions are assumed to be held at identical temperatures. Assuming that junctions J3 and J4 are the same temperature, the Thermocouple Law of Intermediate Metals indicates that the circuit in Figure 3 is electrically equivalent to the circuit in Figure 1. Consequently, any result taken from the circuit in Figure 3 also applies to the circuit illustrated in Figure 1.

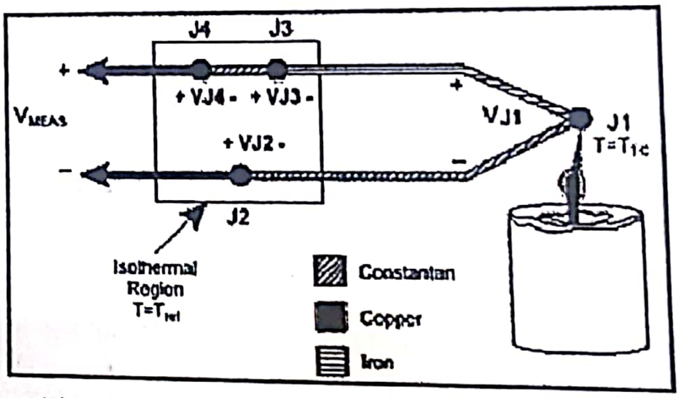


Figure (3): Intermediate Materials effect In Isothermal region.

In Figure 3, junctions J2 and J4 are the same type (copper-constantan); because both are in the isothermal region, J2 and J4 are also the same temperature. Because of the direction of the current through the circuit, J4 contributes a positive Seebeck voltage, and J2 contributes an equal but opposite negative voltage. Therefore, the effects of the junctions cancel each other, and the total contribution to the measured voltage is zero. Junctions J1 and J3 are both iron-constantan junctions, but may be at different temperatures because they do not share an isothermal region. Being at different temperatures, junctions J1, J3 both produce a Seebeck voltage, but with different magnitudes. To compensate for the cold junction J3, its temperature is measured and the contributed voltage is subtracted out of the thermocouple measurement.

## *Experiment Procedure:*

1. Run the **TMT001** Software.

2. A screen named "**Welcome to TMT001**" will appear, containing three buttons: **[Information]**, **[Run the Experiments]** and **[Quit]**.

3. The "**Welcome screen**" is shown in the figure below:

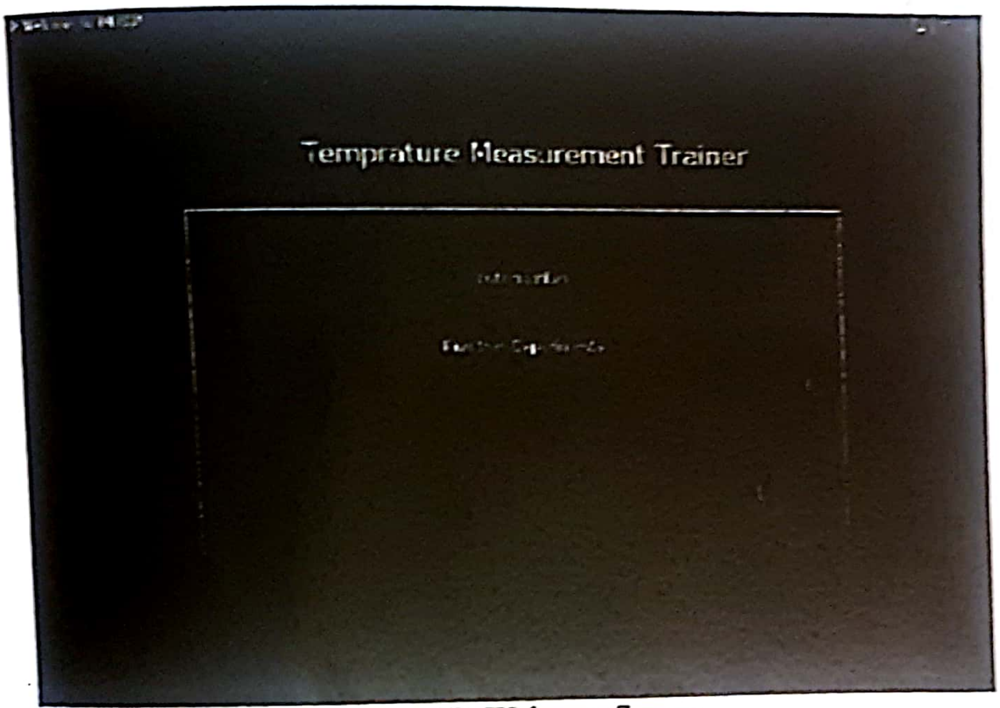


Figure (4): Welcome Screen.

4. **Press the [Information]** button to go to the Information screen.
5. **The "Information Screen"** is shown in the figure below:

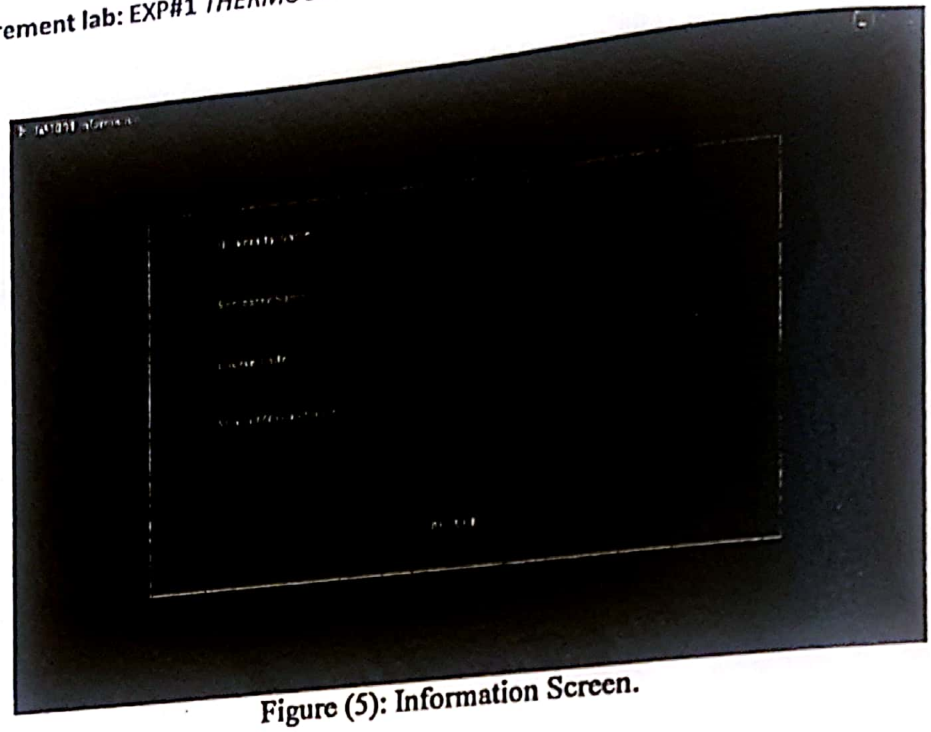

Figure (5): Information Screen.

6. Fill in the fields with your information, Press the **[Accept]** button and a confirmation message will appear asking you to press **[Accept]** the information you have entered, or **[Cancel]** if you need to go back to change anything. Pressing **[Accept]** will let you go back to the **"Welcome Screen"**.
7. Press **[Run the Experiments]** button to go to the **"Experiments screen"**.
8. The **"Experiments Screen"** is shown in the figure 6, containing four experiments; **Thermocouple Characteristics, RTD Characteristics, Thermistor Characteristics** and **Thermometers Comparison.**

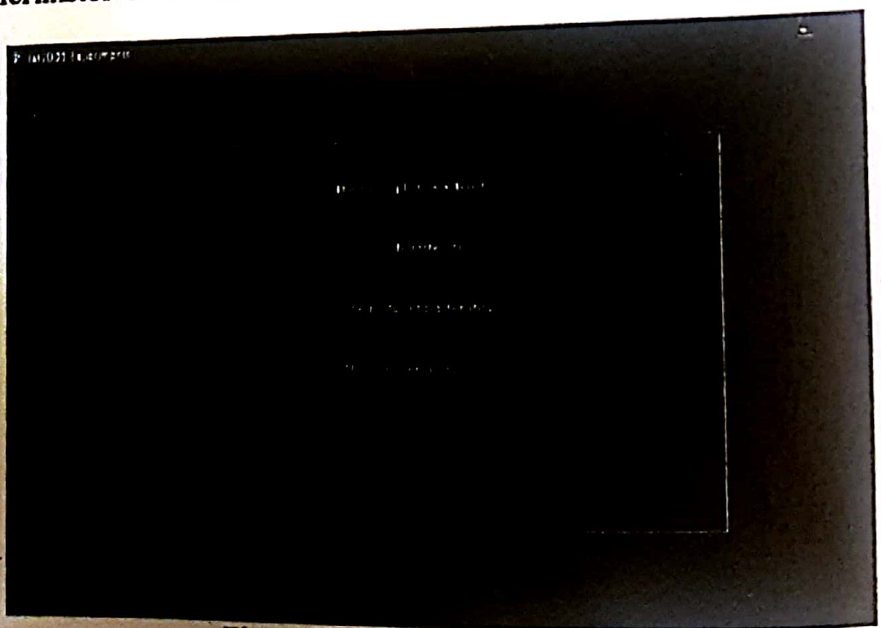

Figure (6): Experiments Screen.

9. Choose Experiment 1: **"Thermocouple Characteristics".**
10. Study the front panel carefully and observe the buttons on the screen.

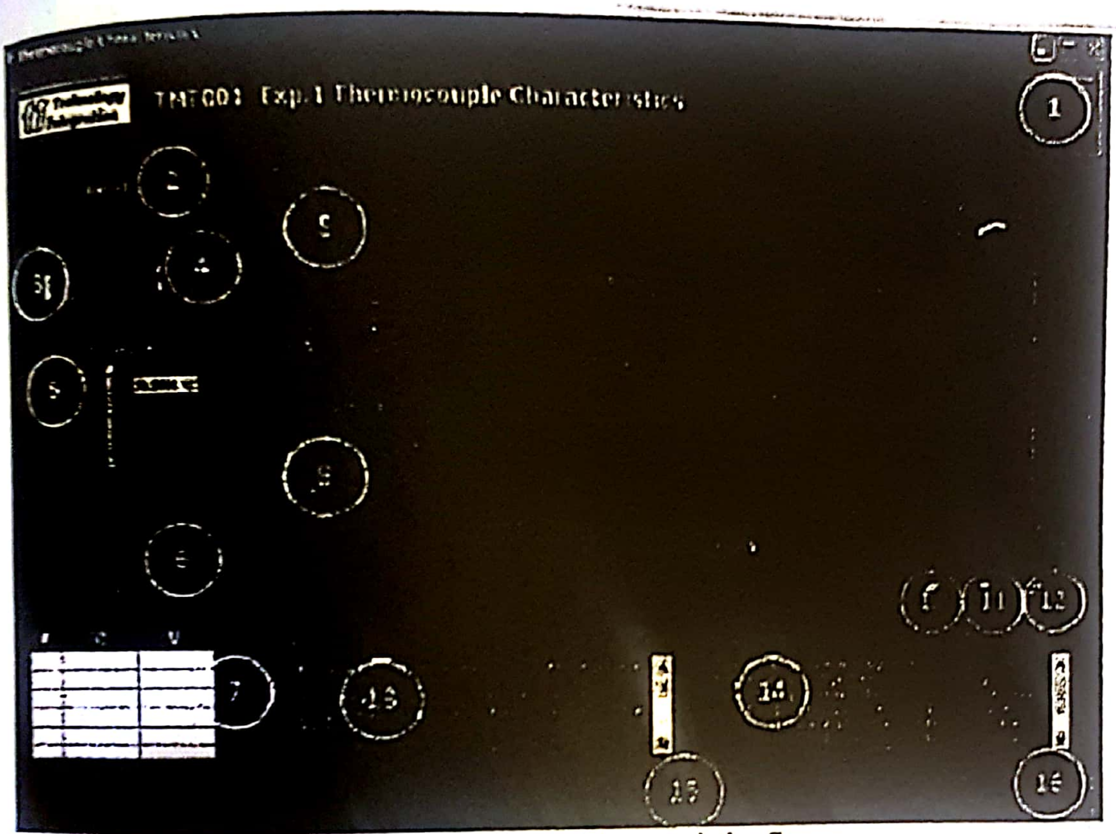

**Figure (7):** Thermocouple Characteristics Screen.

1) **Current Date and Time Indicator.**
2) **Read Button:** To read and plot the current temperature and voltage (resistance) of the current thermometer (here it is the Thermocouple).
3) **Fan Switch:** To turn the Fan ON or OFF.
4) **Heater Switch:** To turn the Heater ON or OFF.
5) **Thermometer Temperature (°C):** Displays the current temperature of the current thermometer.
6) **Thermometer Voltage (Resistance):** Displays the current voltage (resistance) of the current thermometer.
7) **Readings Table:** Displays the current Temperature and Voltage (resistance) readings taken each time the [Read] button is pressed.
8) **Phase Plot:** Contains the Temperature vs. Voltage (Resistance) graph which displays the readings that have been taken by the user. Each point represents the Thermometer Temperature (°C) with its corresponding Voltage (V) or Resistance (Ohm).

9) **Time Trend:** Contains the Temperature vs. Time graph which displays the temperature profile of the thermometer.
10) **Clear Chart Button:** To clear the Phase Plot graph.
11) **Save Report Button:** To save a report, the report will be saved in the **"Temperature Trainer Files"** folder on the desktop.
12) **Print Report Button:** To print a report, the report will be printed using your default printer.
13) **Help Window:** Displays the procedures needed to carry out the experiment
14) **Theory Window:** Displays the conversion theory of the thermometer of the current experiment (how to change from voltage (resistance) to temperature).
15) **Status Bar:** Displays the current Student/Group name as well as the current operating mode (Heating or Cooling).
16) **Quit Button:** To quit from this experiment and return to the **"Experiments"** window.

11. Turn the **Heater** ON by pressing ON the **Heater Switch** on the screen (Heating Mode).
12. Start taking readings by pressing **[Read]** button on different temperature values.
13. The acquired readings appear on the **Temperature-Voltage graph** as red points.
14. Compare the read temperature with the temperature of the **glass thermometer.** Is it the same temperature? Why?
    ..........................................................................................
    ..........................................................................................
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15. Turn the **Heater** OFF by pressing OFF the **Heater Switch** on the screen.
16. Turn the **Fan** ON by pressing ON the **Fan Switch** on the screen (Cooling Mode).
17. Start taking readings by pressing **[Read]** button over different temperature values.
18. Notice that the acquired reading appears on the **Temperature-Voltage graph** as white points.
19. Is the cooling curve the same as the heating curve? Why?
    ..........................................................................................
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20. In order to save the readings you have taken, press **[Save Report]** button, your report will be saved on your desktop in a folder named **Temperature Trainer Files.**
21. To print the report, press **[Print Report]** button.

22. Notice the **Temperature vs. Voltage** curve and answer the following questions:

22.1 Is the curve linear?
   a) Yes
   b) No

22.2 Does the thermocouple equation in the "Theory" window describe the curve on the **Temperature vs. Voltage graph**? If your answer is "No", what is the difference and why?
..............................................................................................
..............................................................................................

23. Choose one of the readings taken before from the **Readings Table** and write down its Voltage (V) and Temperature ( °C) readings:

23.1 Current Voltage (V) ..............................
23.2 Current temperature (°C)...........................
23.3 Apply the current voltage in the thermocouple equation below

$$T = V(1.978425 * 10^{-2}) + V^2(-2.001204 * 10^{-7}) + V^3(1.036969 * 10^{-11}) + V^4(-2.549687 * 10^{-16}) + V^5(3.585153 * 10^{-21}) + V^6(-5.344285 * 10^{-26}) + V^7(5.099890 * 10^{-31})$$

Where: T : Calculated temperature in (°C)
V : Thermocouple voltage in microvolt ($V*10^6$)

23.4 Write down the Calculated temperature (°C).......................
23.5 Compare the calculated temperature with the current temperature.

24. Press **[Clear Chart]** button if you want to clear the chart.
25. Press **[Quit]** button to return to the **"Experiments"** window.

## Conclusions

1. ..............................................................................................
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2. ..............................................................................................
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4. ..............................................................................................
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University Of Jordan
Faculty of Engineering and Technology
Industrial Engineering Department

# Measurement Lab.

## STRAIN GAUGES

Student Name :
Student No. :

GROUP ( )

**Objectives**

Upon completion of this study and the evaluation of experimental measurements, the student will be able to:

- Describe how strain gauge devices are used for measurements,
- Describe the type of circuitry used in connecting strain gauge transducers,
- Describe how a strain gauge should be physically attached to objects.

indirect devices

**Introduction**

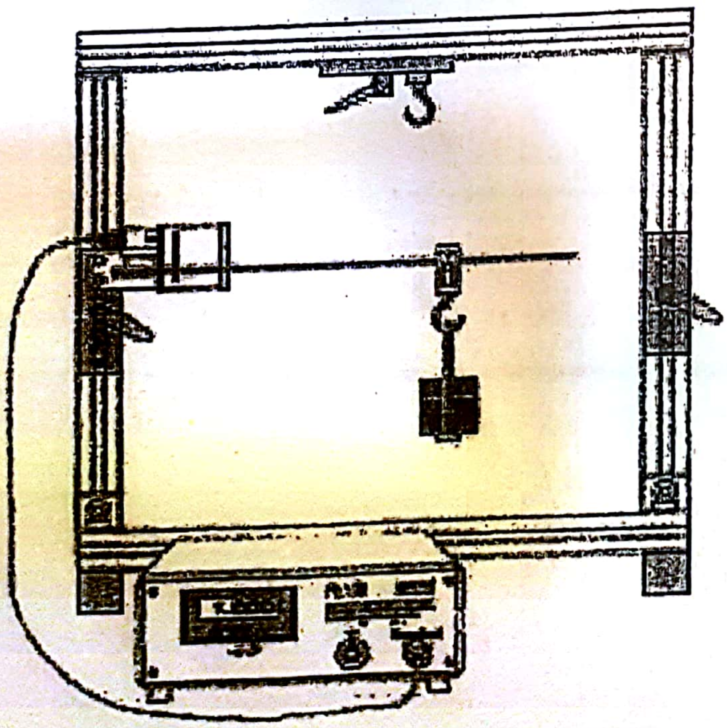
**Strain gauges** permit simple and reliable determination of stress and strain distribution at real components under load. The strain-gauge technique is thus an indispensable part of experimental stress analysis. Widespread use is also made of strain gauges in sensor construction (scales, dynamometers and pressure gauges, torque meters).

All **test objects** are provided with a full-bridge circuit and are ready wired. A Perspex cover protects the element whilst giving a clear view.
The test objects are inserted in a frame and loaded with weights.

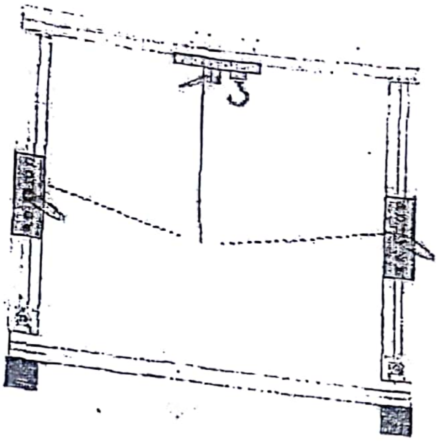
The **measuring amplifier** has a large bright digital LED display, which is still easy to read from a distance. The unit is thus also eminently suited to demonstration experiments.

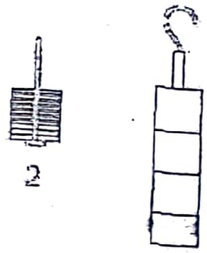
**2 Unit description**

$R = \frac{\rho L}{A}$



### 2.1 Loading frame






The loading frame is made of light-alloy sections and serves to accommodate the different test objects. Various holders (1) are attached to the frame for this purpose. Clamping levers enable these holders to be quickly and easily moved in the grooves of the frame and fixed in position. The training system is provided with two different sets of weights for loading the test objects.

- Small set of weights (2) -----1 - 6 N, graduations 0.5 N for bending experiments

### 2.2 Test objects


#### 2.2.1 Bending beam

The test object used for bending experiments is a clamped steel cantilever beam (4).

- Length L: 385 mm
- Cross section Area:
  h=4.75 mm
  b=19.75 mm
- Modulus of elasticity E: 210000 N/mm2

The strain-gauge element (2) (full-bridge circuit) is attached in the vicinity of the clamping point. Electrical connection is by way of a small PCB and a 5-pin socket (1) with bayonet lock. The strain-gauge configuration can be seen from the adjacent diagram. The element is protected by a Perspex housing. An adjustable slider (3) with hook permits loading with a single force at defined lever arm.

## 2.3 Measuring amplifier


The measuring amplifier with digital 4-position LED display (1) gives a direct indication of the bridge unbalance in mV/V. The connected strain-gauge bridge can be balanced by way of a ten-turn potentiometer (2).

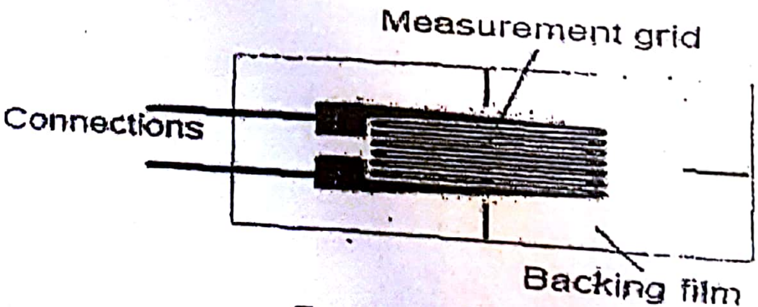
- Range: ± 2.000 mV/V
- Resolution: 1 µV/V.
- Balancing range: ± 1.0 mV/V.
- Nominal strain-gauge resistance: 350 Ω
- Strain-gauge feed voltage :10V
- Power supply: 230V / 50Hz

The unit is envisaged for the connection of strain gauge full bridges. The test objects are connected by way of the cable (4) supplied to the 7-pin input socket (3) on the front.

# 3 Experiments

### *3.1 Principle of strain-gauge technique*

When dimensioning components, the loads to be expected are generally calculated in advance within the scope of design work and the components then dimensioned accordingly. It is often of interest to compare the loads subsequently encountered in operation to the design forecasts. Precise knowledge of the actual load is also of great importance for establishing the cause of unexpected component failure. The mechanical stress is a measure of the load and a factor governing failure. This stress cannot generally be measured directly. As however the material strain is directly related to the material stress, the component load can be determined by way of strain measurement. An important branch of experimental stress analysis is based on the principle of strain measurement.



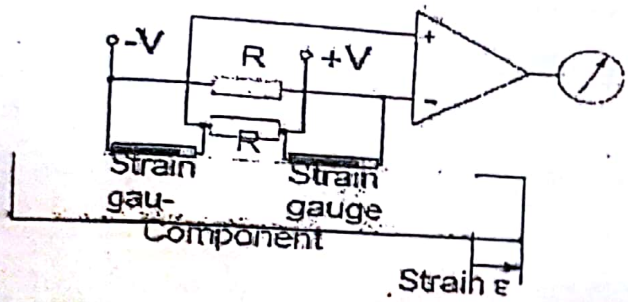

**Foil-type strain gauge (greatly enlarged)**

The use of the strain-gauge technique enables strain to be measured at the surface of the component. As the maximum stress is generally found at the surface, this does not represent a restriction. With metallic strain gauges, the type most frequently employed, use is made of the change in the electrical resistance of the mechanically strained thin metal strip or metal wire. The change in resistance is the combination of tapering of the cross-sectional area and a change in the resistivity. Strain produces an increase in resistance. To achieve the greatest possible wire resistance with small dimensions, it is configured as a grid. The ratio of change in resistance to strain is designated **k**

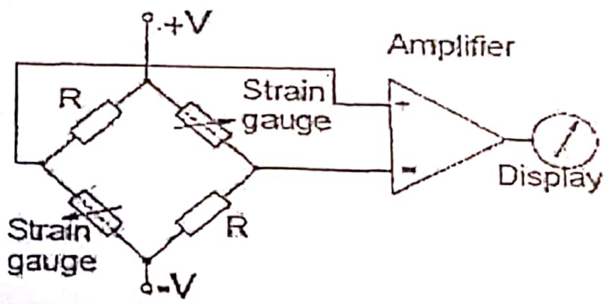
$$k = \frac{\Delta R / R0}{\varepsilon}$$

ε : strain
$R_0$ : resistance at zero point ( no force) Ω
ΔR : change in resistance after applying force Ω

Strain gauges with a large k-factor are more sensitive than those with a small one. The constantan strain gauges used have a **k-factor of 2.05**. In order to be able to assess the extremely small change in resistance, one or more strain gauges are combined to form a Wheatstone bridge, which is supplied with a regulated DC voltage (±V).




Configuration of half bridge on component

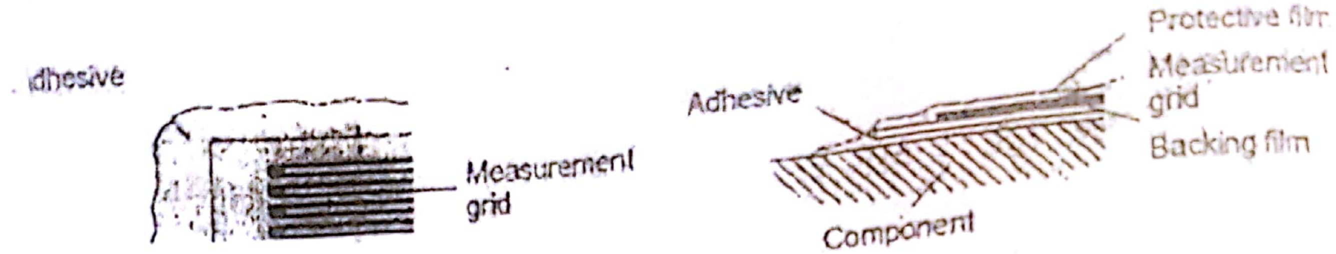



Halve-bridge circuit

The bridge may be fully (full bridge) or only partially (half and quarter bridge) configured with active strain gauges. The resistors R required to complete the bridge are called complementary resistors. The output voltage of the bridge reacts very sensitively to changes in resistance in the bridge branches. The voltage differences occurring are then amplified in differential amplifiers and displayed.

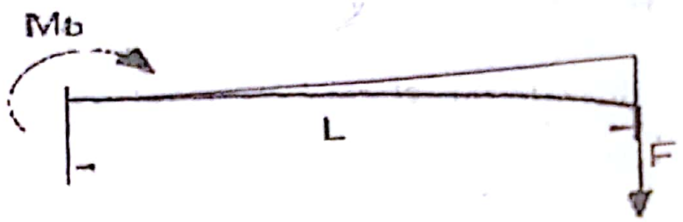
The design of a strain gauge is shown in the adjacent illustration. The wave-form metal strips are mounted on a backing material, e.g. a thin elastic polyimide film and covered with a protective film. Today's metal strips are usually produced by etching from a thin metal foil (foil-type strain gauges). Thin connecting wires are often welded directly to the strain gauge.

The strain gauge is bonded to the component with a special adhesive, which must provide loss-free transmission of the component strain to the strain gauge.




Design of strain gauge

### 3.3 Bending experiment




#### 3.3.1 Fundamentals

The stress at the surface of the bending beam can be calculated from the bending moment $M_b$ and the section modulus $W_y$

$$\sigma = \frac{M_b}{W_y}$$

Bending moment calculated for cantilever beam

$$M_b = -F \cdot L.$$

where F is the load and L the distance between the point at which the load is introduced and the measurement point. The section modulus for the rectangular cross section of width b and height h is

$$W_y = \frac{b h^2}{6}$$

For experimental determination of the bending stresses, the bending beam is provided with two strain gauges each on the compression and tension sides. The strain gauges of each side are arranged diagonally in the bridge circuit. This leads to summation of all changes in resistance and a high level of sensitivity. The output signal $U_A$ of the measuring bridge is referenced to the feed voltage $U_E$. The sensitivity k of the strain gauge enables the strain ε to be calculated for the full bridge as follows

$$\varepsilon = \frac{1}{k} \cdot \frac{U_A}{U_E}$$

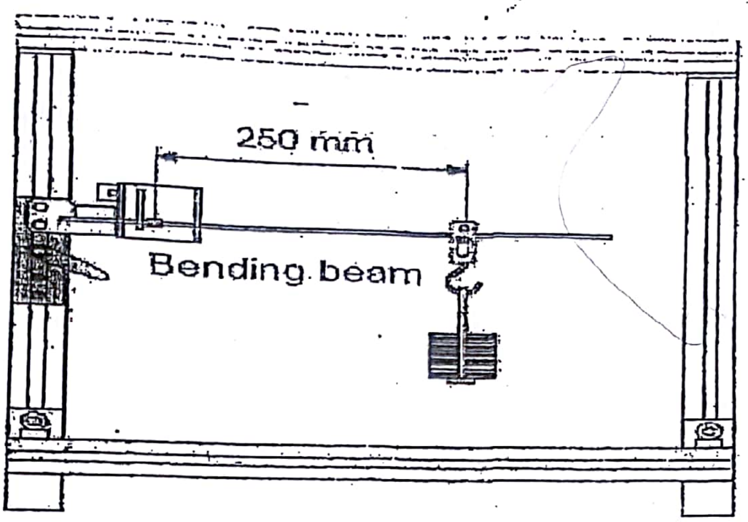
According to Hooke's law the stress being sought is obtained with the modulus of elasticity E (Modulus of elasticity for steel: 210000 N/mm2)

$$\sigma = \varepsilon \cdot E$$

### 3.3.2 Performance of experiment

- Fit bending beam in frame as shown using holder with two pins.
- Connect up and switch on measuring instrument.
- Set slider to distance of 250 mm.
- Use offset adjuster to balance display.
- Load beam with small set of weights.

Increase load in steps and note down reading.




| Bending experiment, lever arm 250 mm | | | | | | | |
|---|---|---|---|---|---|---|---|
| Load in N | 0 | 1 (holder only) | 2 | 3 | 4.5 | 5.5 | 6 |
| Reading in $mV/V.10^{-3}$ | 0 | -0.034 | -0.069 | -0.104 | -0.156 | -0.190 | |

$\frac{U_A}{U_E}$ $10^{-3}$ mV/V

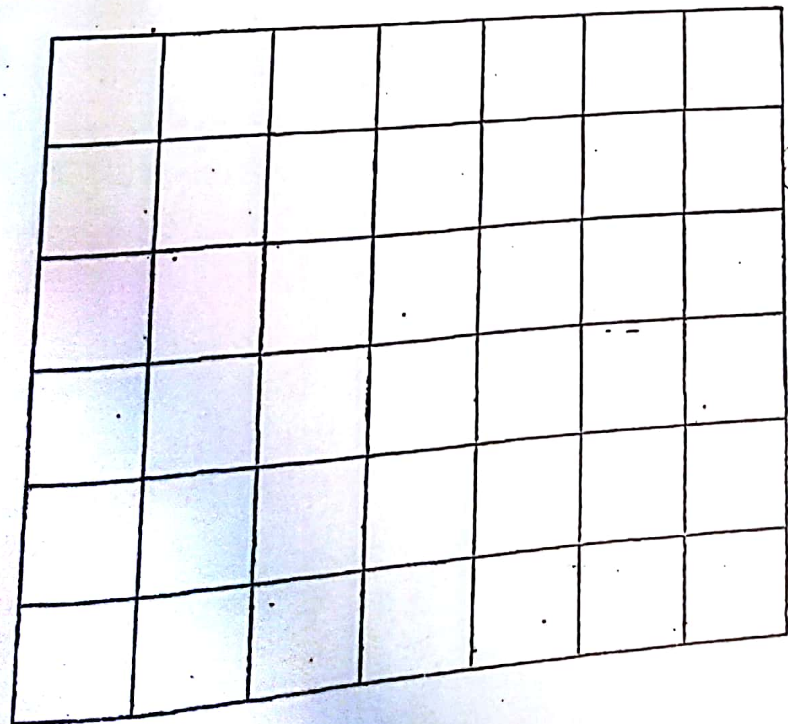
$\frac{V}{V}$ = unitless

① $\varepsilon = \frac{1}{K}\frac{U_A}{U_E}$

$K = 2.05$

**Discussion :**

1. Plot the measurement results in a graph.



② $\sigma_{exp} = E\varepsilon$

③ $\sigma$ – $\varepsilon$

④ $\sigma_{theo}$

$\sigma = \frac{M}{W} = F \cdot L$

W section modulus

$W = \frac{bh^2}{6}$

Scanned by CamScanner

2. Calculate stress and strain.
3. Name two types of strain gauge.
4. Find the slope of the graph and compare the value with calculated one.

**Example:**

The stress is now to be determined for a load of 6.5 N where the reading was $-0.227.10^{-3}$. The following results for the strain

$$\varepsilon = \frac{1}{k} \cdot \frac{U_A}{U_E}$$

$$= \frac{1}{2.05} \cdot (-0.227 \cdot 10^{-3})$$

$$= -0.0001107.$$

The modulus of elasticity for steel of 210000 N/mm2 gives the following stress

$$\sigma = \varepsilon \cdot E$$

$$= -0.0001107 \cdot 210000 = -23.25 \text{ N/mm}^2$$

The measured stress is to be compared to the theoretical result in the following.
The section modulus for the rectangular cross section is $W_y = 74.26$ mm³.

The calculation produces the following stress

$$\sigma = \frac{Mb}{Wy}$$

$$= -6.5 \cdot 250/74.26 = -21.88 \text{N/mm}^2.$$