ME-372 : Heat transfer and Metrology lab

Measurement of Flatness error

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Introduction

Straightness: A line is said to be straight over a given length if the deviation of various points on the line from two mutually perpendicular reference planes remains within stipulated limits.

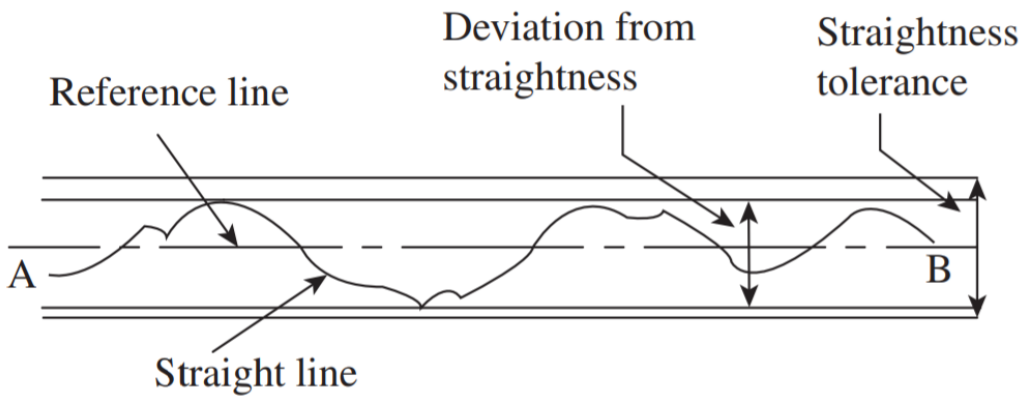


Figure 1: Straightness of a line

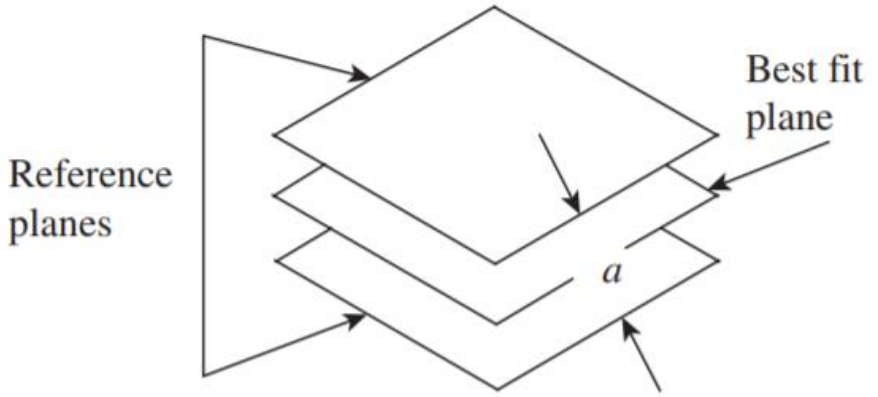


Figure 2: Measurement of flatness error

Flatness is when all points of a surface lie in the same plane.

Flatness error: Flatness error may be defined as the minimum separation of a pair of parallel planes that will just contain all the points on the surface.

Objective

Aim of the experiment: To determine the flatness error of a surface plate with the help of a sensible spirit level

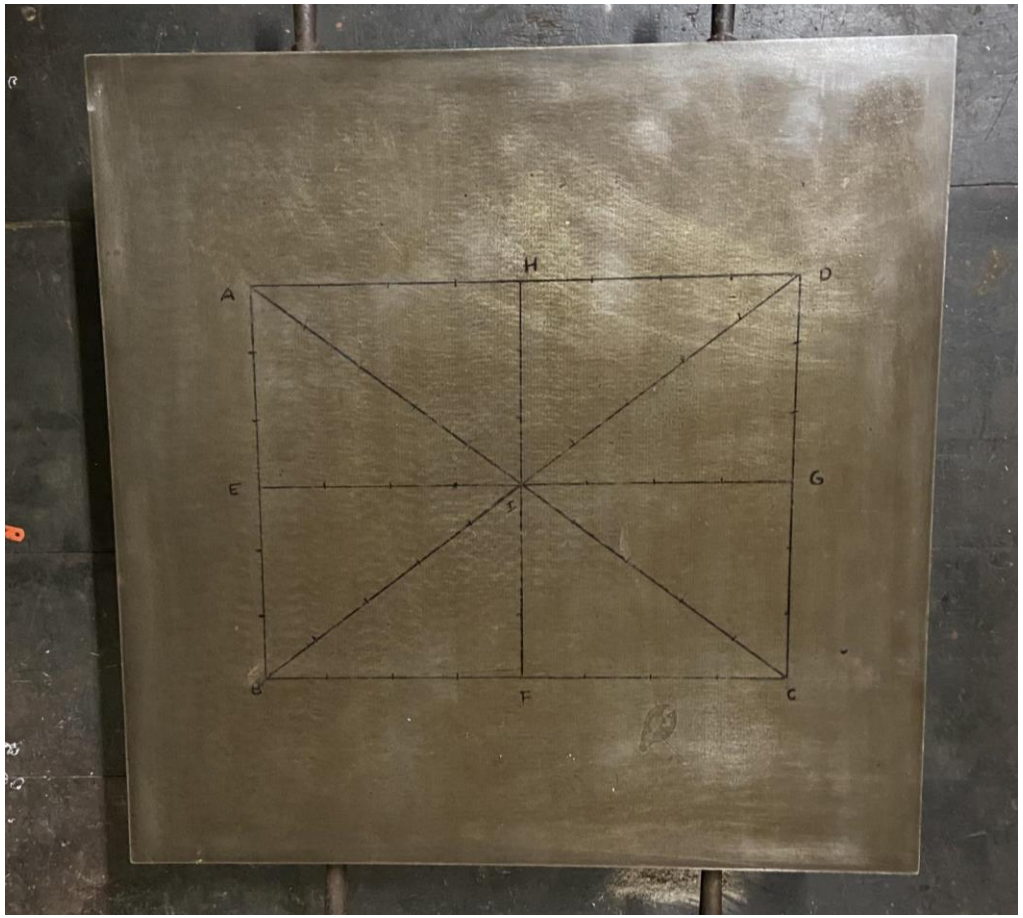


Figure 3: Flat surface specimen

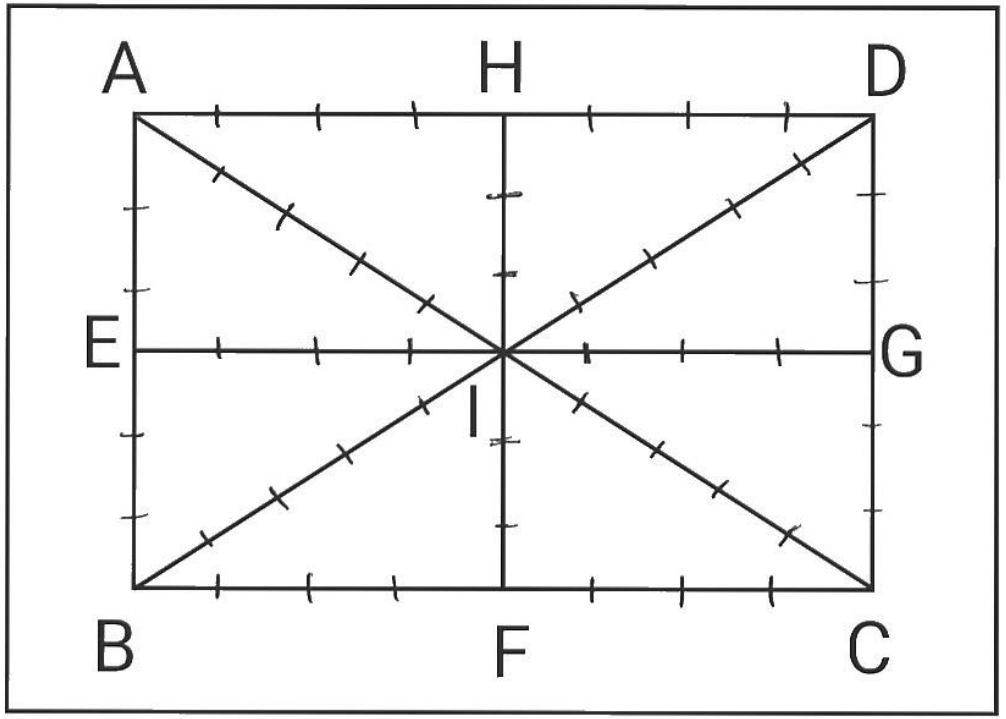


Figure 4: Inline diagram of surface plate

Spirit Level

- A **spirit level**, is an instrument designed to indicate whether a surface is horizontal (level) or at some inclination
- Spirit levels had very slightly curved glass vials with constant inner diameter at each viewing point.
- These vials are incompletely filled with a liquid, usually a colored spirit or alcohol, leaving a bubble in the tube.
- Spirit level basically defines the inclination angle between two points and unit of inclination is mm/m.

Figure 5: Spirit level

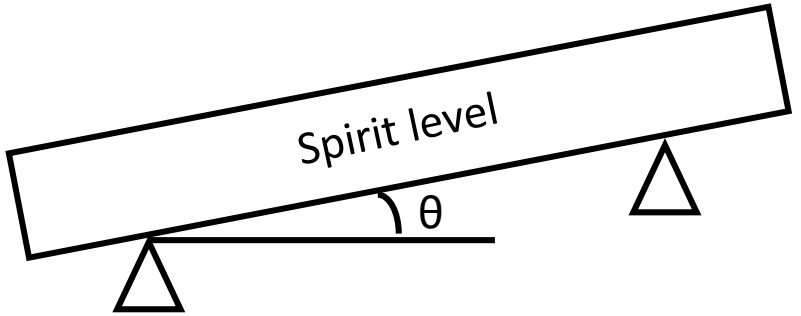
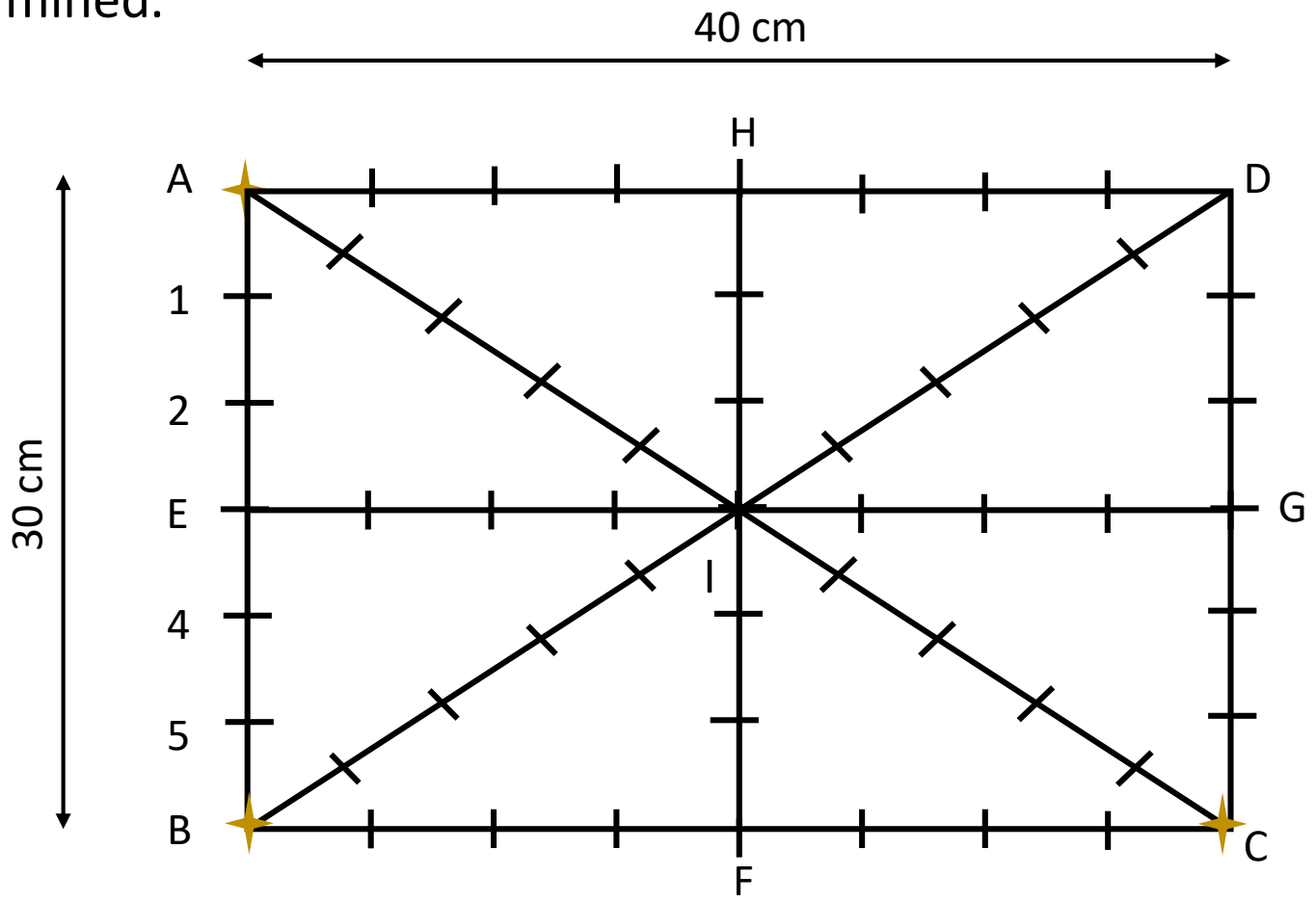


Figure 6: Calculating inclination with spirit level

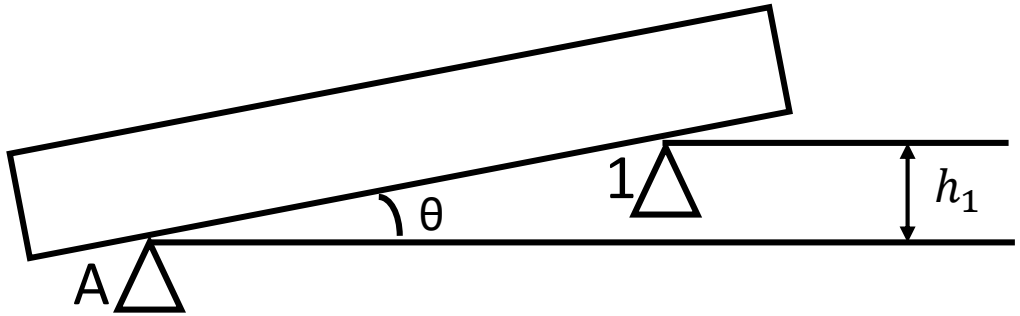
Procedure

- Mark the boundary lines and generators on the surface plate (as shown in Figure 2).
- Lengths of the lines should be integer multiples of a common reading span.
- Choose a reference plane, say ABC, from which the flatness deviations of all the points will be determined.



Procedure

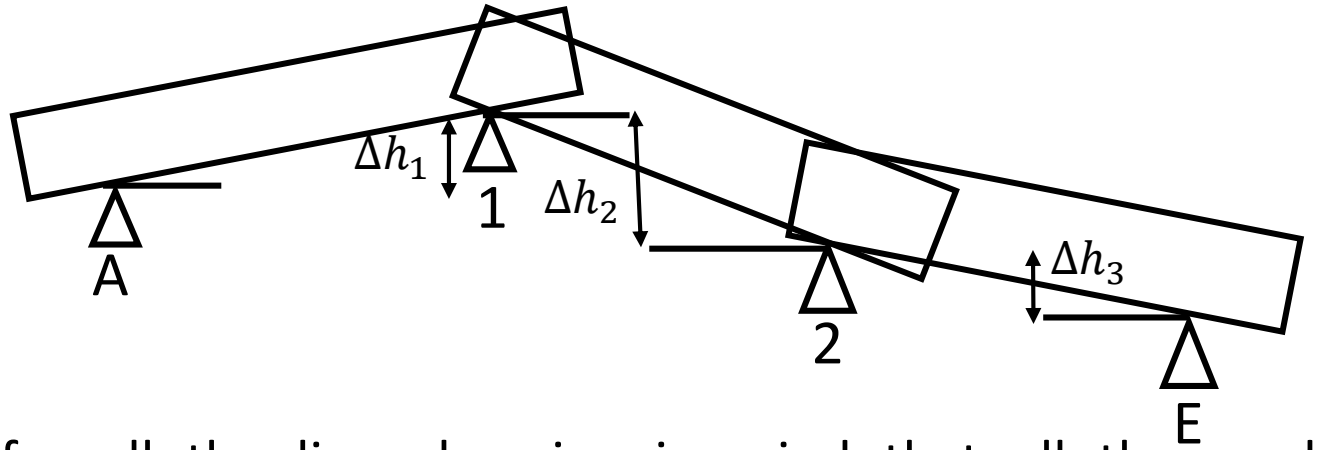
- Place the spirit level on the first span A-1 and note down the deviation of point, with respect to A.



- Repeat the readings for 1-2, 2-E etc. until B and calculate the cumulative value.

$$(\mathrm{A}-1)\quad y_1 = \Delta h_1$$

$$(1-2)\quad y_2 - y_1 = \Delta h_2$$



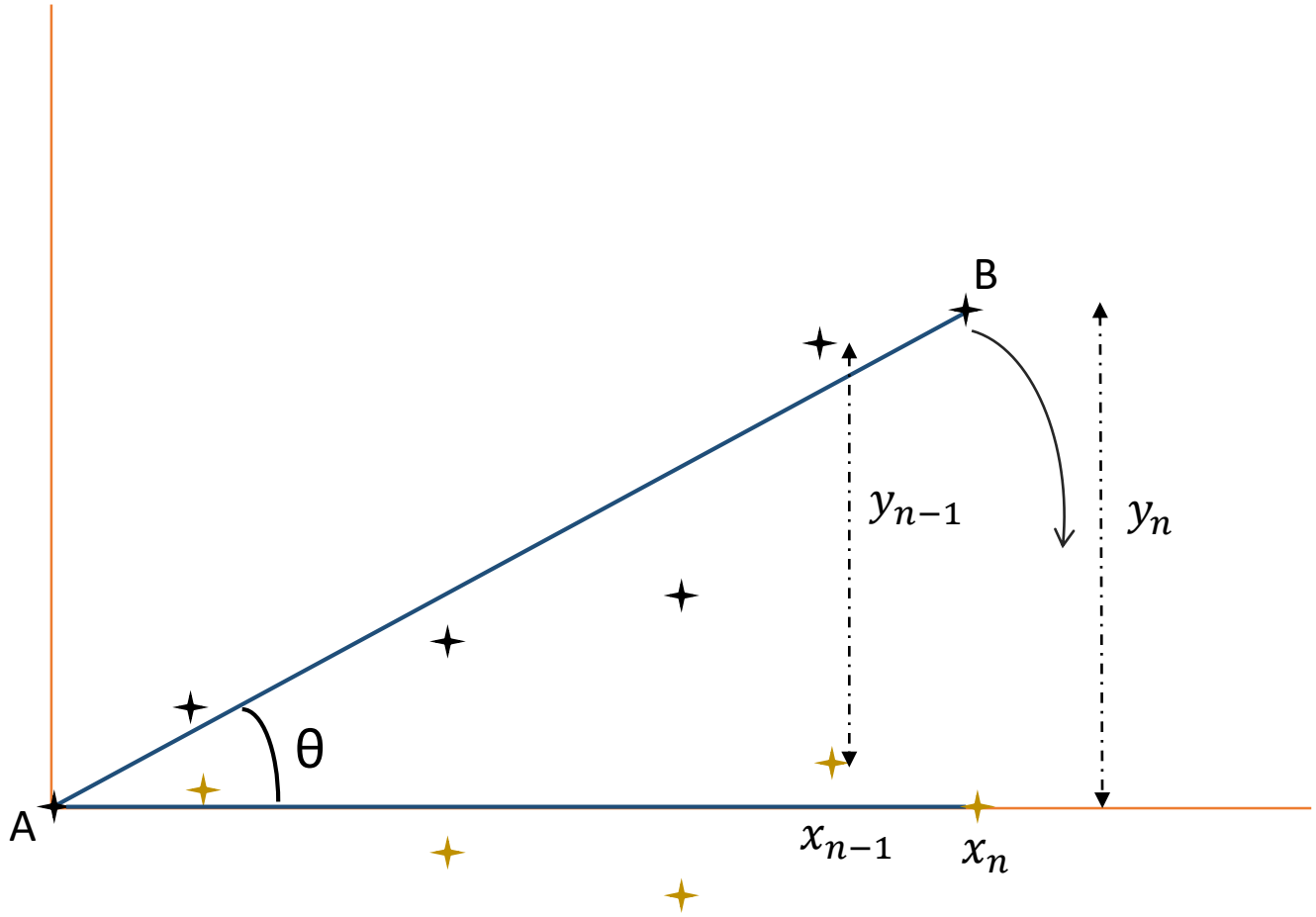
- Repeat the same procedure for all the lines keeping in mind that all the readings independently for all the lines.

Procedure

- Correct all the ends of the lines of the reference plane to zero.

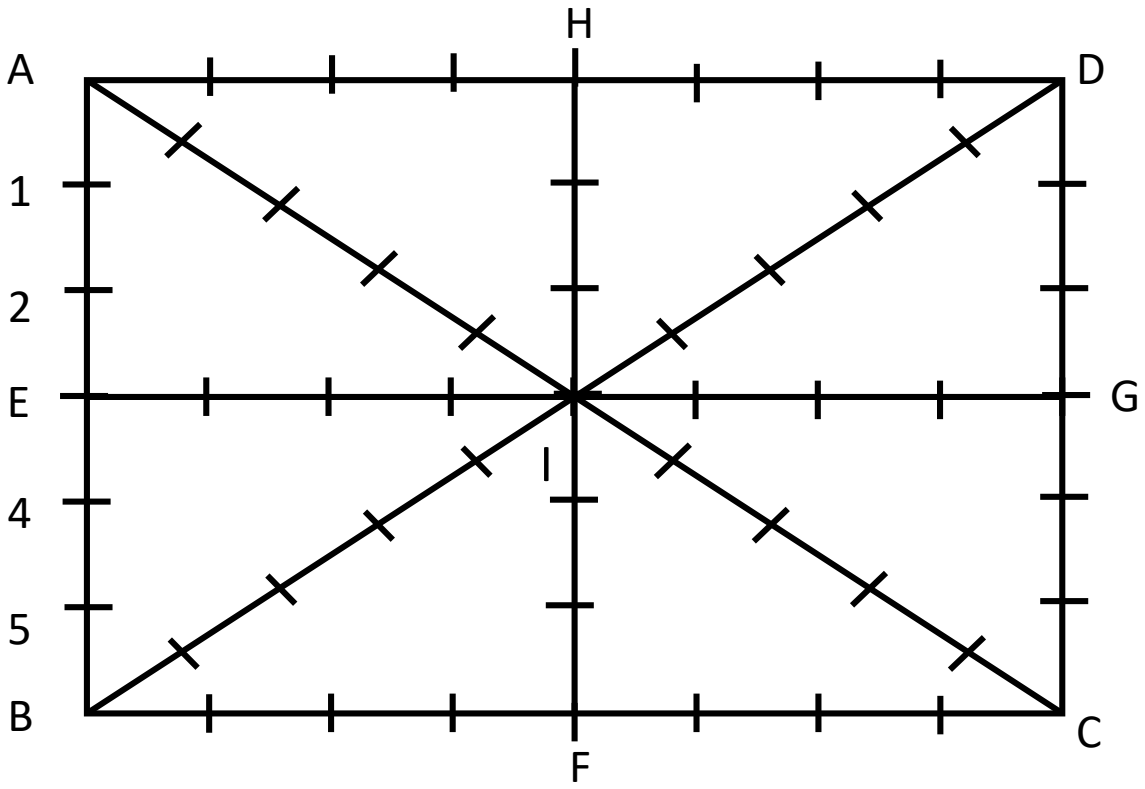
  Assumption: Angle θ is very small

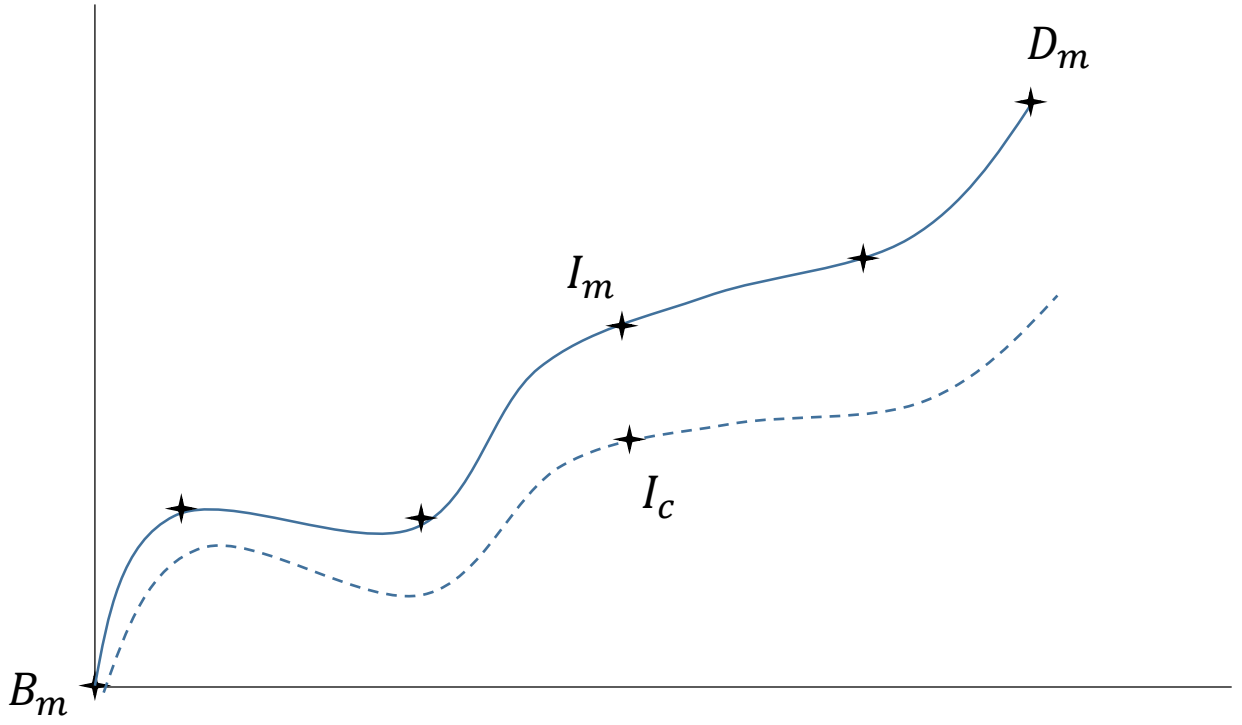
$$y_{n-1} = x_{n-1}\frac{y_n}{x_n}$$



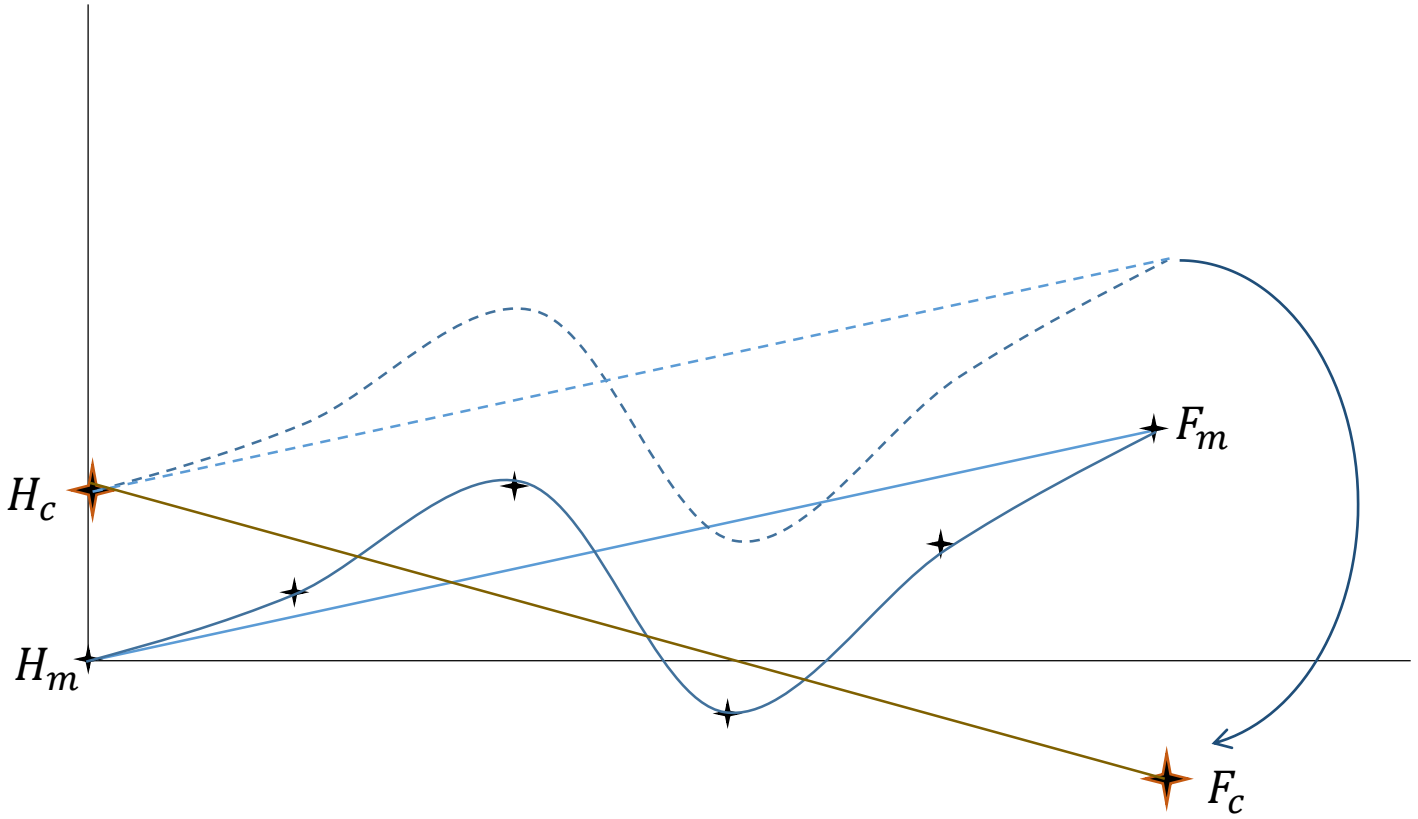
Procedure

- Correct the other lines with respect to the three points on the reference plan.





Procedure

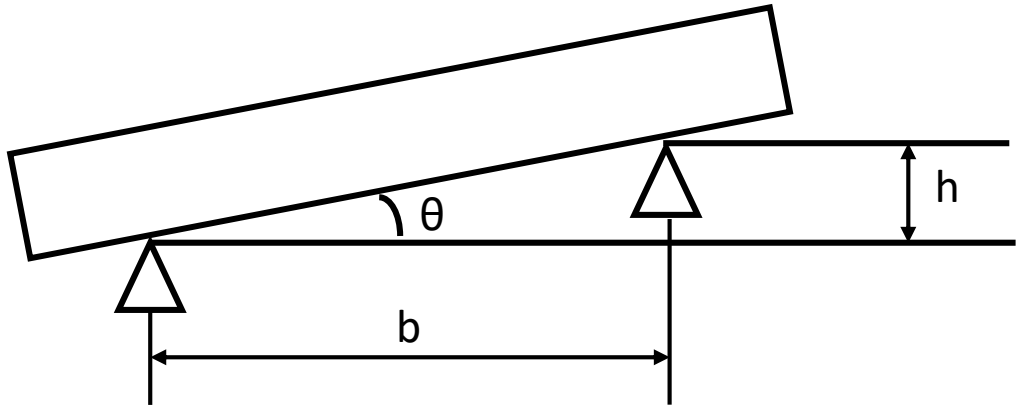


- Thus the deviations of all the points relative to the reference plane chosen are known.
- The minimum distance between a pair of parallel planes that contains all the points chosen on the surface will give the flatness error of the surface

Calculating flatness error

Sensitivity: The sensitivity of a level is given as the change of angle or gradient required to move the bubble by unit distance

$$\tan\theta = 0.02\ mm/m$$



h = height of the point on surface w.r.t a reference
b = separation between two points in XY plane = 5 cm (given)
x = reading value of bubble movement

$$x \tan\theta = \frac{h}{b}$$

$$h = xb \tan\theta$$

Results and Analysis

Question 1. Draw a diagram for the layout of the surface plate and get the cumulative values for all the lines from the measured values provided.

Question 2. Show sample calculations for the corrections of each line and Prepare a table for each line as shown below.

Corrected Heights (AB)			
MEASURED VALUES	CUMMULATIVE VALUES	CORRECTION	CORRECTED VALUES
0			
3			
-1			
2			
4			
-3			
1			

Results and Analysis

Question 3. Plot the corrected values in MATLAB/python or any software. The distance between the farthest points of either side from the reference plane (Z=0) can be the measure of flatness error.

Question 4. Plot the corrected values in MATLAB/python or any software and fit a least square plane. The distance between the farthest points of either side from the least square plane also defines the flatness error.

Question 5. Write conclusions and sources of error.

Report requirement

1. Introduction
2. Objective
3. Procedure
4. Data points tabulation and plotting (experimental readings)
5. Data correction with respect to reference line and plotting the corrected data points
6. Results and conclusions
7. Sources of error