

LAB NUMBER 1

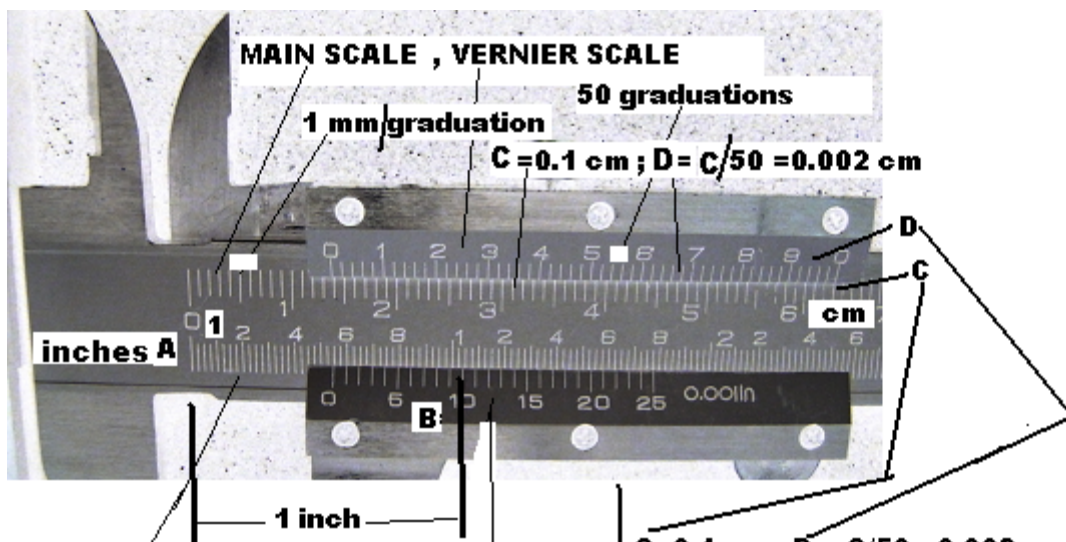
VERNIERS, MICROMETERS AND UNCERTAINTIES

INSTRUCTIONS FOR EXPERIMENTS

ANAND M. SHARAN

SEPT 7, 2010

VERNIER CALIPER



$$A = 0.1 / 4 \text{ inches};$$

$$A = 0.025 \text{ inches}$$

$$B = A / 25 = 0.001 \text{ inches}$$

SUPPOSE WE HAVE

$$\text{READING} = 1 + 3A + 9B$$

$$= 1 + (3 \times 0.025) + (9 \times 0.001)$$

$$= 1 + 0.075 + 0.009 = 1.084 \text{ inches}$$

$$C = 0.1 \text{ cm}; D = C/50 = 0.002 \text{ cm}$$

SUPPOSE WE HAVE

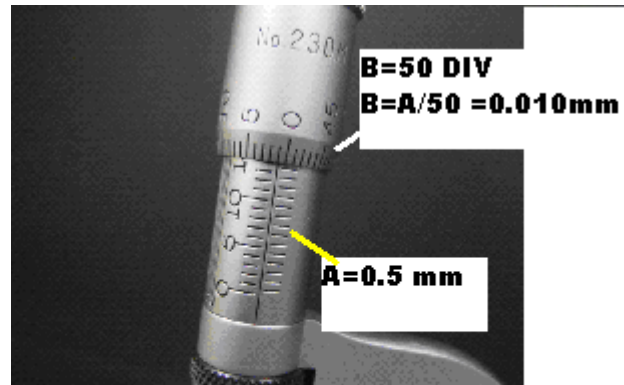
$$\text{READING} = 2 + 3C + 20D$$

$$= 2 + (3 \times 0.1) + (20 \times 0.002)$$

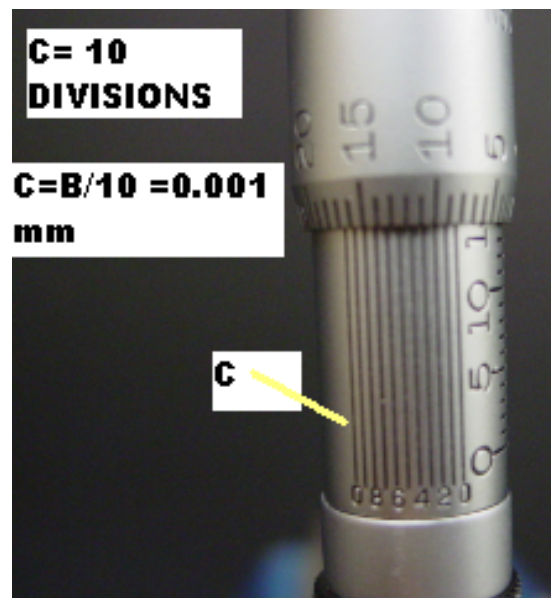
$$= 2 + 0.3 + 0.04$$

$$= 2.340$$

MICROMETER READINGS



$$\begin{aligned}
 \text{READING} &= 2.0 + 1XA + 42 \times B + 9 \times C \\
 &= 2.0 + 0.5 + 0.42 + 0.009 \\
 &= 2.929 \text{ mm}
 \end{aligned}$$



CALCULATING UNCERTAINTIES IN EXPERIMENTS

The algebra is as follows:

A	Quality Measured
U_A	Uncertainty of A

Suppose there are several measurements - A, B, C, D.....then

Addition

$$\begin{aligned} 1) \quad & A \pm U_A \pm B \pm U_B \\ & = (A + B) \pm (U_A + U_B) \end{aligned}$$

SUBTRACTION

$$\begin{aligned} 2) \quad & A \pm U_A - B \pm U_B \\ & = (A - B) \pm (U_A + U_B) \end{aligned}$$

MULTIPLICATION

$$\begin{aligned} 3) \quad & (A \pm U_A) \times (B \pm U_B) \\ & = (AB) \pm (U_A + U_B) \end{aligned}$$

DIVISION

$$4) \quad \frac{A \pm U_A}{B \pm U_B} = \left(\frac{A}{B} \right) \pm (U_A + U_B)$$

5) A constant has zero uncertainty. For example, the acceleration due to gravity,

$$g = 9.81 \text{ m / s}^2$$

$$g \pm (U_g = 0)$$

HOW TO EXPRESS UNCERTAINTY

Let us look at the following instruments for measurements.

Lab #1 Uncertainties

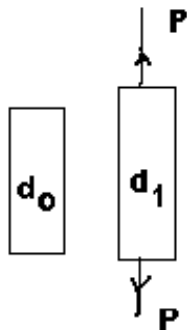
Metrology: The science of measurement.

Length Measurements:

	<u>Range</u>	<u>Resolution</u> Smallest Main Scale Graduation	<u>Repeatability</u> <u>Uncertainty</u>
Rule	0-300 mm	1 mm	$\pm 1 \text{ mm}$
Vernier Caliper	0-150 mm	0.05 mm	$\pm 0.05 \text{ mm}$
Micrometer	0-25 mm	0.002 mm	$\pm 0.002 \text{ mm}$

Examples:

length of 10 mm (ruler) = $10 \text{ mm} \pm 1 \text{ mm}$ **or** $10 \text{ mm} \pm 10\%$



EXAMPLE

Let us look at the application of the above in the measurement of Stress-Strain curve. The readings are as follows:

d_0	d_1	Load	Instrument	Instrument
1.2	1.1	4000kg	Micrometer Resolution (0.002)	Balance Resolution (1kg)

$$\text{strain} = \frac{d - d_o}{d_o} = \frac{(1.1) - (1.2)}{1.2} = \frac{-0.1}{1.2}$$

$$\frac{\left\{ 1.1 \angle \left(\frac{0.002}{1.1} \right) \right\} - 1.2 \angle \left(\frac{0.002}{1.2} \right)}{1.2 \angle \left(\frac{0.002}{1.2} \right)}$$

$$\frac{(1.1 \angle 0.0001818) - 1.2 \angle 0.001666}{1.2 \angle (0.001666)}$$

$$= 0.08333 \angle (0.005138)$$

$$\text{stress} = \frac{\text{force}}{\text{Area}} = \frac{400 \angle \left(\frac{1}{400} \right) \times 9.81 \angle 0}{\pi \frac{d_o^2}{4} = \frac{31416}{4} \times (1.2^2 L(2 * 0.00166))}$$

$$= \frac{3924 \angle (0.0025 + 0)}{0.7854 \times \{(1.2 \angle 0.0016)(1.2 \angle 0.0016)\}}$$

$$= 4996 \angle (0.0025 + 0 + 0.0016 + 0.0016)$$

$$= 4996 \angle 0.0057 \quad \frac{N}{m^2}$$

$$\text{Modulus of Elasticity} = \frac{\text{Stress}}{\text{Strain}} = \frac{4996 \angle 0.0057}{0.0833 \angle 0.005738}$$

$$= (4996/0.08333) \pm (0.0057 + 0.005138)$$

$$= 59954.39818 \pm 0.010838$$

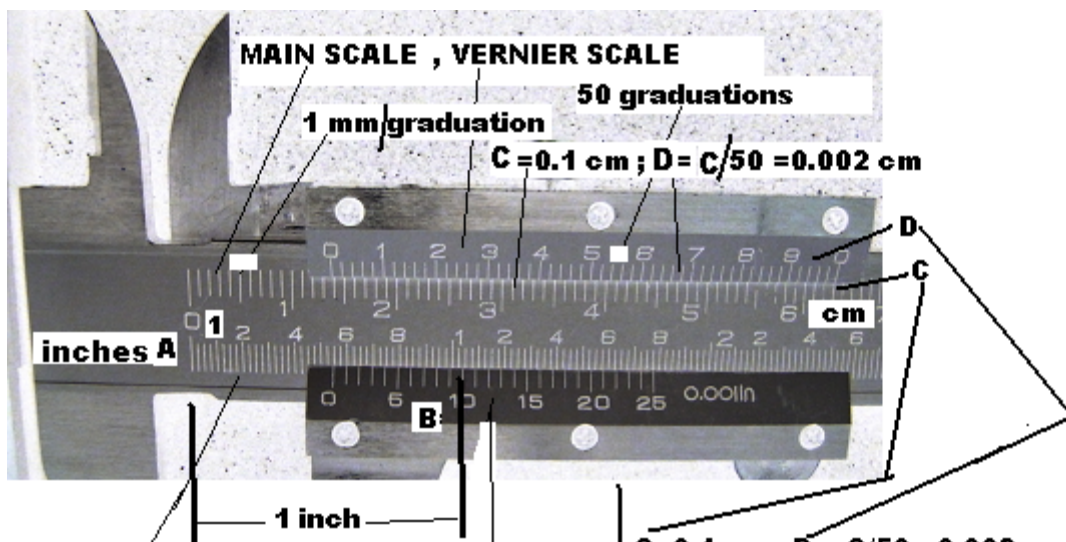
It can also be expressed as

$$= 59954.39818 \pm [(59954.39818) \times (0.010838)]$$

$$= 59954.39818 \pm [\mathbf{649.7857675}]$$

$$= \mathbf{60604.18395} \text{ Maximum ; } \mathbf{59304.61241} \text{ Minimum}$$

VERNIER CALIPER



$$A = 0.1 / 4 \text{ inches};$$

$$A = 0.025 \text{ inches}$$

$$B = A / 25 = 0.001 \text{ inches}$$

SUPPOSE WE HAVE

$$\text{READING} = 1 + 3A + 9B$$

$$= 1 + (3 \times 0.025) + (9 \times 0.001)$$

$$= 1 + 0.075 + 0.009 = 1.084 \text{ inches}$$

$$C=0.1 \text{ cm}; D= C/50 =0.002 \text{ cm}$$

SUPPOSE WE HAVE

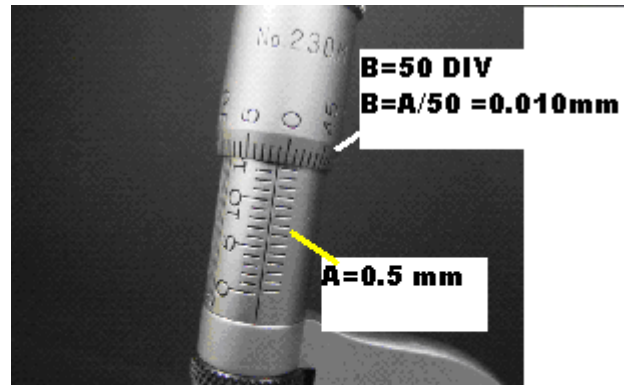
$$\text{READING} = 2 + 3C + 20D$$

$$= 2 + (3 \times 0.1) + (20 \times 0.002)$$

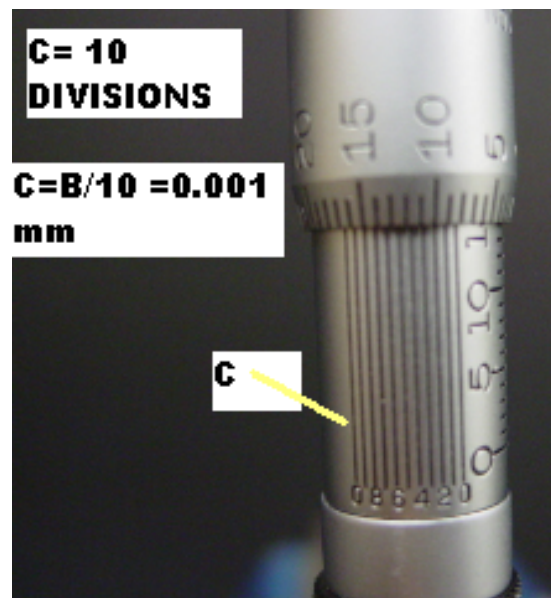
$$= 2 + 0.3 + 0.04$$

$$= 2.340$$

MICROMETER READINGS



$$\begin{aligned}\text{READING} &= 2.0 + 1XA + 42 \times B + 9 \times C \\ &= 2.0 + 0.5 + 0.42 + 0.009 \\ &= 2.929 \text{ mm}\end{aligned}$$



CALCULATING UNCERTAINTIES IN EXPERIMENTS

The algebra is as follows:

A	Quality Measured
U_A	Uncertainty of A

Suppose there are several measurements - A, B, C, D.....then

Addition

$$\begin{aligned} 1) \quad & A \pm U_A \pm B \pm U_B \\ & = (A + B) \pm (U_A + U_B) \end{aligned}$$

SUBTRACTION

$$\begin{aligned} 2) \quad & A \pm U_A - B \pm U_B \\ & = (A - B) \pm (U_A + U_B) \end{aligned}$$

MULTIPLICATION

$$\begin{aligned} 3) \quad & (A \pm U_A) \times (B \pm U_B) \\ & = (AB) \pm (U_A + U_B) \end{aligned}$$

DIVISION

$$4) \quad \frac{A \pm U_A}{B \pm U_B} = \left(\frac{A}{B} \right) \pm (U_A + U_B)$$

5) A constant has zero uncertainty. For example, the acceleration due to gravity,

$$g = 9.81 \, \text{m} / \text{s}^2$$

$$g \pm (Ug = 0)$$

HOW TO EXPRESS UNCERTAINTY

Let us look at the following instruments for measurements.

Lab #1 Uncertainties

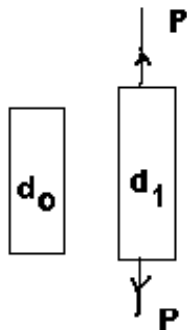
Metrology: The science of measurement.

Length Measurements:

	<u>Range</u>	<u>Resolution</u> Smallest Main Scale Graduation	<u>Repeatability</u> <u>Uncertainty</u>
Rule	0-300 mm	1 mm	$\pm 1 \text{ mm}$
Vernier Caliper	0-150 mm	0.05 mm	$\pm 0.05 \text{ mm}$
Micrometer	0-25 mm	0.002 mm	$\pm 0.002 \text{ mm}$

Examples:

length of 10 mm (ruler) = $10 \text{ mm} \pm 1 \text{ mm}$ **or** $10 \text{ mm} \pm 10\%$



EXAMPLE

Let us look at the application of the above in the measurement of Stress-Strain curve. The readings are as follows:

d_0	d_1	Load	Instrument	Instrument
1.2	1.1	4000kg	Micrometer Resolution (0.002)	Balance Resolution (1kg)

$$\text{strain} = \frac{d - d_o}{d_o} = \frac{(1.1) - (1.2)}{1.2} = \frac{-0.1}{1.2}$$

$$\frac{\left\{ 1.1 \angle \left(\frac{0.002}{1.1} \right) \right\} - 1.2 \angle \left(\frac{0.002}{1.2} \right)}{1.2 \angle \left(\frac{0.002}{1.2} \right)}$$

$$\frac{(1.1 \angle 0.0001818) - 1.2 \angle 0.001666}{1.2 \angle (0.001666)}$$

$$= 0.08333 \angle (0.005138)$$

$$\text{stress} = \frac{\text{force}}{\text{Area}} = \frac{400 \angle \left(\frac{1}{400} \right) \times 9.81 \angle 0}{\pi \frac{d_o^2}{4} = \frac{31416}{4} \times (1.2^2 L(2 * 0.00166))}$$

$$= \frac{3924 \angle (0.0025 + 0)}{0.7854 \times \{(1.2 \angle 0.0016)(1.2 \angle 0.0016)\}}$$

$$= 4996 \angle (0.0025 + 0 + 0.0016 + 0.0016)$$

$$= 4996 \angle 0.0057 \quad \frac{N}{m^2}$$

$$\text{Modulus of Elasticity} = \frac{\text{Stress}}{\text{Strain}} = \frac{4996 \angle 0.0057}{0.0833 \angle 0.005738}$$

$$= (4996/0.08333) \pm (0.0057 + 0.005138)$$

$$= 59954.39818 \pm 0.010838$$

It can also be expressed as

$$= 59954.39818 \pm [(59954.39818) \times (0.010838)]$$

$$= 59954.39818 \pm [\mathbf{649.7857675}]$$

$$= \mathbf{60604.18395} \text{ Maximum ; } \mathbf{59304.61241} \text{ Minimum}$$