1. Objective
Familiarisation with calliper and the statistical method of calculating uncertainties. Utilization of calliper on the measurement of length and then, based on the measurements, perform statistical operations to calculate uncertainties.

2. Equipment
Digital calliper, measurable objects (plate and tube)

3. Theory

3.1. Digital Caliper
A **digital caliper** is a precision instrument used for measuring length, internal and external dimensions, and depth [1]. Like traditional calipers, it has two sets of jaws:

- The **main jaws** are used to measure the **external dimensions** of an object.
- The **smaller, upper jaws** are designed to measure the **internal dimensions**, such as the inside diameter of a pipe or hole.

Additionally, the caliper includes a **depth rod** (or depth gauge), which extends from the end of the sliding frame and is used to measure the **depth of holes or recesses**.

Unlike a vernier or dial caliper, a digital caliper displays measurements electronically on an **LCD screen**, typically with an accuracy of **0.01 mm**. This removes the need for manual interpretation of scales.

Digital calipers are **pre-calibrated**, so there's no need to add a correction value (like the 10 mm marked on traditional calipers).

3.1.1. Diagram
Here is a schematic of a digital caliper showing its main components:

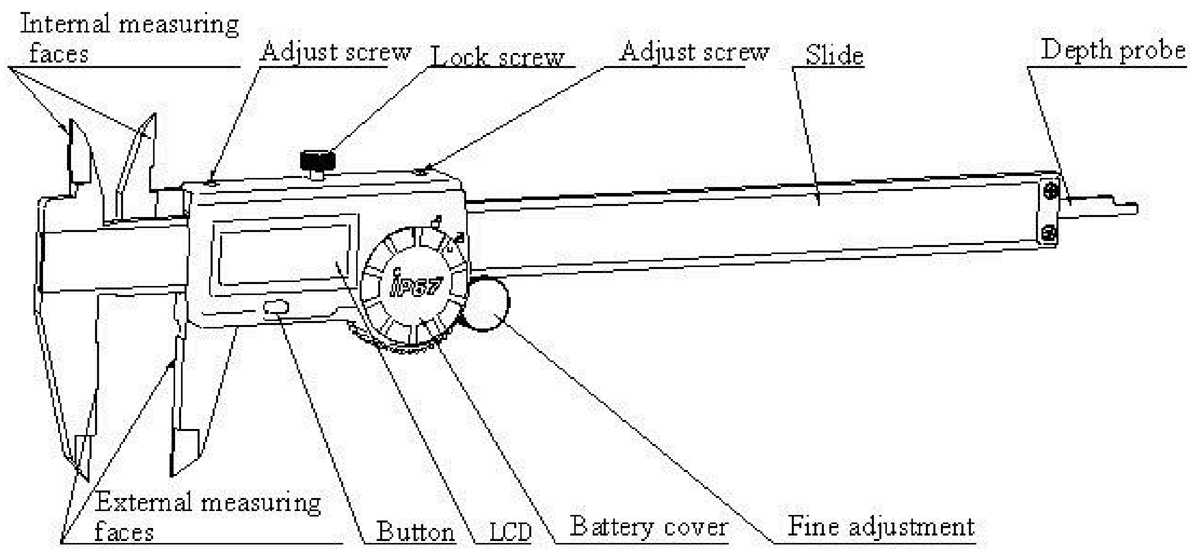

Figure 1: Labeled diagram of a digital caliper. [2]

4. Measurements With Digital Caliper and Calculating Uncertainties

4.1. Type B uncertainty evaluation

1. $U_{B_1}(x)_m = 2.0 \cdot \frac{0.02}{3} \approx 0,013$
2. $U_{B_2}(x)_l = 2.3 \cdot 0.005 = 0.0115$
3. $U_B = \sqrt{U_{B_1}^2 + U_{B_2}^2} \approx 0.017$

4.2. The measurement of the thickness of the plate by calliper

Trial nr.	d, mm	$d_j - \overline{\mathrm{d}}, \mathrm{mm}$	$\left(d_j - \overline{\mathrm{d}}\right)^2, \mathrm{mm}^2$
1	7.70	−0.1	0.01
2	7.80	0	0
3	7.86	0.06	0.0036
4	7.85	0.05	0.0025
5	7.81	0.01	0.0001
6	7.85	0.05	0.0025
7	7.79	−0.01	0.0001
8	7.74	−0.06	0.0036
9	7.82	0.02	0.0004
10	7.78	−0.02	0.0004

$\overline{\mathrm{d}}$ = 7.80 mm

4.2.1. Type A uncertainty evaluation

1. $\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2 = 0,0313$
2. $\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)} = 0,2817$
3. $\sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 0,531$
4. $U_A = 2,3 \cdot \sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 1,221$

4.2.2. Combined uncertainty evaluation

$U_c(\overline{\mathrm{x}}) = \sqrt{U_A^2 + U_B^2} = 1.221$

4.3. The measurement of the internal diameter of the tube by calliper

Trial nr.	d, mm	$d_j - \overline{\mathrm{d}}, \mathrm{mm}$	$\left(d_j - \overline{\mathrm{d}}\right)^2, \mathrm{mm}^2$
1	30.34	0	0
2	30.29	−0.05	0.0025
3	30.18	−0.06	0.0036
4	30.08	−0.26	0.0676
5	30.42	0.08	0.0064
6	30.40	0.06	0.0036
7	30.47	0.13	0.0169
8	30.47	0.13	0.0169

9	30.41	0.07	0.0049
10	30.39	0.05	0.0025

$\overline{\mathrm{d}}$ = 30.34 mm

4.3.1. Type A uncertainty evaluation

1. $\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2 = 0.1249$
2. $\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)} \approx 0.014$
3. $\sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 0.118$
4. $U_A = 2,3 \cdot \sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 0.27$

4.3.2. Combined uncertainty evaluation

$U_c(\overline{\mathrm{x}}) = \sqrt{U_A^2 + U_B^2} = 0.72$

4.4. The measurement of the external diameter of the tube by calliper

Trial nr.	d, mm	$d_j - \overline{\mathrm{d}}$, mm	$\left(d_j - \overline{\mathrm{d}}\right)^2$, mm^2
1	31.55	0.01	0.0001
2	31.34	−0.2	0.04
3	31.33	−0.21	0.0441
4	31.28	−0.26	0.0676
5	31.92	0.38	0.1444
6	31.58	0.04	0.0016
7	31.55	0.01	0.0001
8	31.54	0	0
9	31.61	0.07	0.0049
10	31.83	0.29	0.0841

$\overline{\mathrm{d}}$ = 31.54 mm

4.4.1. Type A uncertainty evaluation

1. $\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2 = 0.3869$
2. $\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)} \approx 0.043$
3. $\sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 0.207$
4. $U_A = 2,3 \cdot \sqrt{\frac{\sum_{i=1}^{10} (x_i - \overline{\mathrm{x}})^2}{10(10-1)}} \approx 0.477$

4.4.2. Combined uncertainty evaluation

$U_c(\overline{\mathrm{x}}) = \sqrt{U_A^2 + U_B^2} = 0.477$

4.5. Conclusion

The digital caliper provided precise measurements for all three tasks: plate thickness, tube internal diameter, and tube external diameter.

1. Plate thickness: mean = 7.80 mm with combined uncertainty $U_C \approx 1.22$ mm.

2. Tube internal diameter: mean = 30.34 mm with combined uncertainty $U_C \approx 0.72$ mm.
3. Tube external diameter: mean = 31.54 mm with combined uncertainty $U_C \approx 0.48$ mm.

Bibliography

[1] "Calipers." [Online]. Available: https://en.wikipedia.org/wiki/Calipers#Digital_caliper

[2] "INSTRUCTIONS FOR IP67 DIGITAL CALIPER TROUBLESHOOTING." [Online]. Available: https://anyimeasuring.com/guide/instructions-for-ip67-digital-caliper-troubleshooting.html