

EXPERIMENT 1

Measurement, Measurement Error and
Basic Dimensional Metrology

Materials Processing Laboratory

Student Name / Surname

Student ID

Group

Date

Instructor

EXPERIMENT OVERVIEW

In this introductory experiment, students learn how to select and use basic measuring instruments, record data with appropriate significant figures, quantify measurement error and repeatability, and use measured dimensions to calculate simple material properties such as density.

1. Learning Outcomes

- Distinguish accuracy, precision, resolution, repeatability, error and uncertainty.
- Select an appropriate measuring instrument according to the required resolution and specimen geometry.
- Use a steel ruler, Vernier caliper, outside micrometer and laboratory balance correctly.
- Record measurements with proper units and significant figures.
- Calculate mean value, absolute error, relative error, percentage error and standard deviation.
- Evaluate the influence of instrument resolution and repeated measurements on data quality.
- Calculate specimen volume and density from experimentally measured values.

2. Background and Theory

Measurement is the quantitative comparison of an unknown physical quantity with an accepted standard. In materials engineering, reliable measurements are essential for process control, quality assurance, dimensional inspection, property determination and reproducible experimentation. A numerical result is meaningful only when its unit, instrument resolution and measurement uncertainty are considered.

2.1 Key Terms

Term	Definition
Precision	Closeness of repeated measurements to one another.
Resolution	Smallest change in the measured quantity that can be distinguished by the instrument.
Repeatability	Agreement of measurements made under the same conditions by the same method.
Systematic error	A consistent bias that shifts measurements in the same direction (e.g., zero error or calibration error).
Random error	Unpredictable variation caused by small changes in reading, positioning, environment or operator technique.
Uncertainty	A quantitative statement describing the range within which the true value is reasonably expected to lie.

Term	Definition
Accuracy	Closeness of a measured value to the accepted or reference value.

2.2 Basic Statistical Treatment of Repeated Measurements

For n repeated measurements $x_1, x_2, \dots, x_n$, the arithmetic mean provides the best simple estimate of the measured quantity:

Mean value: $\bar{x} = (x_1 + x_2 + \dots + x_n) / n$
Absolute error: $E_a = x_n - x_r $
Relative error: $E_r = x_n - x_r / x_r$
Percentage error: $E\% = (x_n - x_r / x_r) \times 100$
Sample standard deviation: $s = \sqrt{[\sum (x_i - \bar{x})^2 / (n - 1)]}$

where $\bar{x}$ is the measured (or mean) value and x_r is the accepted/reference value. When no certified reference value is available, comparison should focus on instrument-to-instrument differences, repeatability and expected resolution rather than "percentage error."

2.3 Significant Figures and Reporting

- Do not report more decimal places than the measuring instrument can justify.
- Always write the unit together with the measured or calculated value.
- For repeated measurements, keep one or two extra digits during intermediate calculations and round only the final result.
- Report mean values and standard deviation using compatible decimal places, e.g., 12.46 ± 0.03 mm.

3. Equipment and Specimens

Equipment / Specimen	Typical Resolution	Main Use
Steel ruler	1 mm	Rapid dimensional measurement
Vernier caliper	0.02 or 0.05 mm*	External, internal and depth measurements
Digital laboratory balance	0.01 g or 0.001 g*	Mass measurement
Metallic specimens	—	Rectangular, cylindrical and/or sheet specimens

*Use the actual resolution stated on the instrument available in the laboratory.

4. Safety and Good Laboratory Practice

- Wear laboratory coat and closed shoes; use safety glasses when required by the instructor.
- Check specimens for sharp edges before handling and use gloves if necessary.
- Do not force the jaws of a caliper or the spindle of a micrometer against the specimen.
- Use the micrometer ratchet or friction thimble to apply a consistent measuring force.
- Keep measuring faces clean. Dust, oil or metal particles can cause measurable error.
- Do not place specimens directly on a balance if they are hot, wet or contaminated.

5. Experimental Procedure

- Record the instrument type, measuring range and resolution for each measuring device used.
- Inspect the zero position of the Vernier caliper and micrometer. Record any observable zero error before measuring specimens.
- Measure the assigned specimen dimension using a steel ruler. Repeat the reading three times and record all values.

4. Measure the same dimension using the Vernier caliper. Repeat the measurement five times. Remove and reposition the specimen between readings.
5. Measure the specimen mass using the laboratory balance. Repeat three times if permitted by the instrument setup.
6. For one selected dimension, calculate the mean and standard deviation of the repeated measurements. Compare the spread obtained with different instruments.

6. Data Recording

Table 1. Instrument Information

Instrument	Measuring Range	Resolution	Zero Error	Remarks
Steel ruler				
Vernier caliper				
Laboratory balance				

Table 2. Repeated Dimensional Measurements

Instrument	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5	Mean
Steel ruler						
Vernier caliper						
Laboratory balance						

Table 3. Statistical Evaluation of a Selected Dimension

Quantity	Result	Unit	Notes
Mean, $\bar{x}$			
Standard deviation, s			
Reference value, x_r			
Absolute error, E_a			
Percentage error, $E\%$			