VIENNA UNIVERSITY OF TECHNOLOGY

FACULTY OF PHYSICS

LABORATORY III

Laboratory Report

Elasticity Modulus

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1 Elasticity Modulus of Tension Rods

1.1 Fundamentals

The elasticity modulus (Young's modulus) E describes the relationship between stress and strain in the elastic deformation region. For a tension rod under axial load:

$$E = \frac{\sigma}{\varepsilon} = \frac{\frac{F}{A}}{\Delta \frac{L}{L_0}} \tag{1}$$

where F is the applied force, A is the cross-sectional area, ΔL is the elongation, and L_0 is the original length. The measurement uses strain gauges with a bridge circuit configuration.

1.2 Setup

Equipment:

- Bridge extension device
- Tension rods (Aluminum, Steel, Brass, Plexiglas)
- Strain gauge measurement system
- Calibrated weights or voltage source
- Digital multimeter

Material Specifications:

- Aluminum: $D = 14.85$ mm, $d = 3.7$ mm
- Steel: $D = 15$ mm, $d = 2.2$ mm
- Brass: $D = 15.8$ mm, $d = 3$ mm
- Plexiglas: $D = 15.2$ mm, $d = 7.7$ mm

K-factor: $k = 2.03 \pm 1\%$ (pre-calibrated)

1.3 Procedure

1. Switch the bridge extension device to 1/2 position
2. Connect the first tension rod to the bridge extension
3. Wait 5 minutes for thermal equilibration
4. For each material, perform 4 measurement series:
   - Series with 5V and 2.5V excitation voltage, OR
   - Series with 2 kg and 5 kg loading
5. Take at least 6 measurements per series
6. Record all voltage readings and corresponding loads
7. Repeat for all four materials

1.4 Measurement Values

Data Table Template:

Material	Load (kg)	Voltage (V)	Strain (με)	Stress (MPa)	Trial
Al					
Steel					
Brass					
Plexiglas					

1.5 Data Analysis

1. Calculate cross-sectional area: $A = \frac{\pi}{4}(D^2 - d^2)$
2. Calculate stress: $\sigma = \frac{F}{A}$
3. Calculate strain from voltage readings: $\varepsilon = \frac{U}{k \cdot U_{\text{bridge}}}$
4. Plot stress vs. strain for each material
5. Determine E from the slope of the linear region
6. Perform error propagation analysis considering individual measurement uncertainties
7. Compare experimental values with literature values

2 Bending Beam Analysis

2.1 Fundamentals

For a cantilever beam under point load, the deflection w is related to the applied force F by:

$$w = \frac{FL^3}{3EI} \tag{2}$$

where L is the beam length, E is the elasticity modulus, and I is the second moment of area. The relationship between bending moment and curvature is:

$$M = EI\kappa \tag{3}$$

2.2 Setup

Equipment:

- Cantilever beam setup
- Displacement measurement system (dial gauge or LVDT)
- Calibrated weights
- Ruler for length measurements
- Caliper for cross-section measurements

Beam Configuration:

- Length L to be measured
- Cross-section dimensions to be determined
- Support conditions: fixed-free (cantilever)

2.3 Procedure

1. Set up the cantilever beam with proper clamping
2. Ensure the beam is horizontal using a level
3. Position the displacement measurement device at the free end
4. Apply loads incrementally (suggested: 0.5, 1.0, 1.5, 2.0 kg)
5. Wait for stabilization between each load increment
6. Record deflection for each load
7. Repeat measurements 3 times for statistical analysis
8. Unload and check for permanent deformation

2.4 Measurement Values

Data Collection:

Load F (N)	Deflection w (mm)	Trial 1	Trial 2	Trial 3
0	0			

4.9				
9.8				
14.7				
19.6				

Beam Geometry:

- Length $L =$ mm
- Width $b =$ mm
- Height $h =$ mm
- Second moment of area $I = \frac{bh^3}{12} =$ mm⁴

2.5 Data Analysis

1. Plot load F vs. deflection w
2. Determine the slope $k = \frac{\Delta F}{\Delta w}$
3. Calculate theoretical deflection: $w_{\text{theory}} = \frac{FL^3}{3EI}$
4. Compare experimental slope with theoretical prediction
5. Calculate experimental elasticity modulus: $E_{\text{exp}} = \frac{FL^3}{3Iw}$
6. Analyze linearity and determine measurement uncertainty
7. Calculate percentage error compared to known material properties
8. Discuss sources of experimental error (beam self-weight, clamping effects, measurement precision)

Error Analysis:

- Systematic errors: calibration, geometric measurements
- Random errors: measurement repeatability, environmental factors
- Propagation of uncertainties through calculations

Expected Results: Compare experimental values with typical elasticity moduli for common materials (Steel: 200 GPa, Aluminum: 70 GPa).

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