CENTRAL SCIENTIFIC COMPANY

OPERATING INSTRUCTIONS

Complete Young's Modulus Apparatus with Dial Indicator
No. 31400-01

1. Purpose

The Complete Young's Modulus Apparatus with Dial Indicator is a device used to determine Young's modulus of elasticity of a wire by stretching.

2. Method

A long vertical wire, securely fastened at its upper end, is stretched by attaching known weights. The extension, or stretch, for a given applied force as well as the cross section and the original length are measured. From these quantities and the applied force, Young's modulus of elasticity is calculated.

3. Theory

It is found by experiment that when a body is deformed, the deformation of the body is proportional to the magnitude of the forces that have caused the deformation. This proportionality holds over a considerable range. The theory of elasticity is based upon the proportionality of the applied forces to the deformation; the proportionality is expressed mathematically by Hooke's Law. The applied force per unit area of the cross section that is subjected to the force is called the stress. The value of the stress for which Hooke's law just ceases to hold is called the elastic limit of the substance. The elastic limit may also be defined as the magnitude of applied stress that produces the maximum amount of recoverable deformation.

The fractional change in the dimensions of a body produced by a system of forces in equilibrium is called a strain.

Even within the limits of perfect elasticity, different bodies show distinct differences in their behavior. Some recover their form immediately after removal of the force, while others, though they recover it ultimately, take considerable time to do so. This delay in recovering the original condition of the substance is called the elastic after-effect or elastic lag.

When a metal wire is stretched beyond its elastic limit and its cross section is reduced, for example when it has been drawn through a die, its structure is changed internally. These changes progress with repeated drawings and the hardness and elasticity of the material are profoundly affected. Keeping such changes in mind, the student should not expect experimental results to compare exactly with the accepted values for the modulus of elasticity given in the tables.

When a wire is stretched, there is not only a change in its length but also a much smaller change in its diameter. Young's modulus of elasticity, **Y**, takes into account only the change in length — the longitudinal strain — which occurs. Young's modulus of elasticity is used to measure the force applied to a lengthened wire as a ratio to the deformation of the wire, $\mathbf{Y} = \sigma / \mathbf{e}$, where σ is the stress applied and **e** is the strain or deformity. The longitudinal stress, synonymous with the applied forces, is measured in terms of force per unit area, $\sigma = \mathbf{F} / \mathbf{A}$. This strain **e** is the change in length per unit length, $\Delta \mathbf{L} / \mathbf{L}$.

If **L** represents the initial length of the wire (Figure 1), **r** its average radius, and Δ **L** the stretch produced by the weight of a mass **Mg**, where **M** is a suspended mass, then:

$$\text{Young's Modulus} = \frac{\sigma\ (\text{stress})}{e\ (\text{strain})} = \frac{Mg / \pi r^2}{\Delta L / L} = \frac{MgL}{\pi r^2 \Delta L}$$

which can be written:

$$Y = \frac{M}{\Delta L} \cdot \frac{gL}{\pi r^2} \qquad (1)$$

Mass (kg)	Elongation (mm)
1.0	0.19
2.0	0.39
3.0	0.59
4.0	0.86
6.0	1.18
7.0	1.36
8.0	1.64
9.0	1.69
10.94	2.09
11.94	2.25
12.94	2.42
13.94	2.66

Figure 1 Typical Values of Elongation vs. Applied Mass

4. Apparatus

The apparatus consists of a heavy steel tripod base with leveling screws, two steel support rods 150cm long, an upper yoke to securely hold a collet that grips the wire to be tested, and a center yoke holding a dial indicator sensitive to movements of 0.01mm. The collet will grip wires ranging up to 1.2mm in diameter. The dial indicator senses wire movement via a small lever arm resting on top of a lower pin vise.

5. Procedure

The dial indicator may need to be assembled to the center yoke. If this is the case, loosen the set screw in the side of the center yoke with the provided hex key wrench. Set the dial indicator into the hole with the push arm down and tighten the set screw. Place the dial indicator lever and then the sleeve onto the screw and screw it into the bottom of the indicator push arm. The upper end of the wire to be tested, is secured in the collet by first threading it up through the center hole in the upper yoke and then through the small hole in the collet. The wire should be extended through the collet by about 1/2", bent in a loop, and reinserted back down the collet as far as it will go. The two set screws in the side of the collet should be tightened with the small Allen wrench provided. The collet will then fit into the small recess bored in the upper part of the hole that is drilled in the center of the upper yoke. The lower end of the wire should pass through the hole in the center yoke and then through the pin vise which should be brought in contact with the underside of the dial indicator lever. The end of the wire should be wrapped around the weight hanger three times and twisted into a loop. Leave at least 2cm of space between the bottom of the weight hanger and the lower support base. The

center yoke and lower pin vise should be adjusted to leave at least 1 meter between the upper yoke and lower pin vise. As weights are added to the weight hanger, the wire is loaded and it stretches, allowing the dial indicator to move.

Now move the dial indicator into position with its lever resting on the top edge of the lower pin vise. Adjust the lower pin vise until the dial indicator reads near its zero point and lock the pin vise into position. Since the wire may have some slack or bends in it at this point, the first reading of the dial indicator may be spurious. Upon adding weight to the weight hanger, indicator readings become more consistent.

When loading the wire, note that after the first few additions of weight the stretch produced for each 1kg load is approximately constant. The elastic limit of the wire has been reached when at high loads the stretch per 1kg load begins to increase. When this has happened, stop loading the wire and note the total load. Remain below this value during further experiments. The following data should be recorded during the experiment: the load (the sum total of all weight supported by the wire); indicator readings for each load (note that the dial indicator is operating backwards so that the current value of the stretch is given by the initial reading minus the current reading); final and initial wire diameters; and final and initial wire lengths (both length dimensions being measured between the two pin vises).

Errors: The most likely sources of error are: slippage of the wire in the pin vise, initial kinks present in the wire, and the experimenter exceeding the elastic limit of the wire. In all of these cases, the dial indicator will show a continued lengthening of the wire even though the load remains constant. Also, the wire may not be exactly round. To ensure an average cross-section measurement, choose two or three different locations along its length; at each location, measure the diameter in several cross-section directions, using a micrometer. The average of the micrometer readings for a selected location should compare favorably to the others.

6. Interpretation of Data

Please refer to Figures 1 and 2.

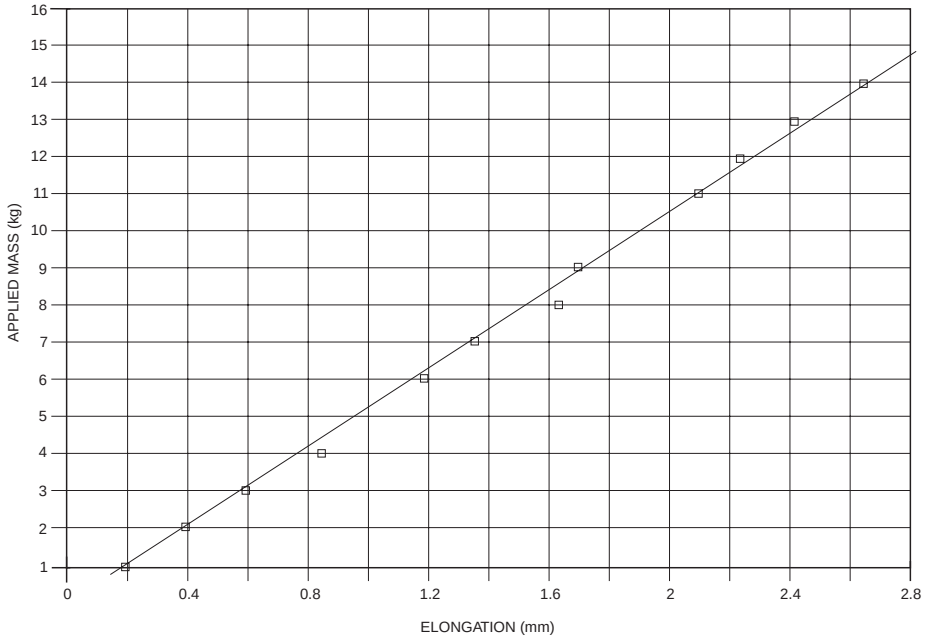

Figure 2 Plot of Elongation vs. Applied Mass

Figure 1 consists of typical values of elongation versus applied load. Figure 2 is a plot of this data illustrating the linear relationship between elongation and applied load.

From equation (1): $Y = \frac{M}{\Delta L} \cdot \frac{gL}{\pi r^2}$

In the example experiment:

$L = 0.90cm$
$r = 0.032cm$
$M / \Delta L = 51153.85g/cm$
$g = 980cm/sec^2$
$Y = 51153.85g/cm \bullet \frac{(980cm/sec^2)\,(0.90cm)}{\pi\,(0.032cm)^2} = 14.02 \times 10^{11} g/cm\text{-}sec^2$

7. Maintenance

The Complete Young's Modulus with Dial Indicator needs no special maintenance and should provide trouble-free service. If you should experience any difficulty with this apparatus, please contact Central Scientific Company, giving details of the problem. To ensure better service, please do not return any apparatus to Central Scientific Company until we have sent you authorization.

8. Copyright Notice

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