VL-G1: DETERMINATION OF THE YOUNG'S MODULUS OF THE MATERIAL OF A WIRE

Objectives:

➢ To acquaintance with the Hooke's Law.

➢ To study the elasticity of a metal wire by measuring its property known as Elastic Modulus.

System requirement:

Computer (Desktop/Laptop), Operating systems: Windows, Youngs Moduls_vle (zipped) File.

Advise:

Students are advised to follow the **procedures written in this manual very strictly** while performing the experiment. **Do not try to explore anything else in the experiment**.

Theory:

When the deforming force is applied to a body in such a manner that its length is changed, longitudinal or linear strain is produced in the body. The internal force of reaction or the restoring force trying to restore its length. Restoring force acts along the length of the body and its magnitude per unit cross-sectional area is the normal stress. The ratio of the change in the length of the body to its initial length is known as longitudinal strain. According to Hooke's law, the ratio of this normal stress and the longitudinal strain is called Young's modulus of elasticity, Y.

Thus, if a uniform cylindrical wire of length L and cross-section area A is stretched in length by applying a force F acting along its length, the internal restoring force equals the external force in the equilibrium state, then

$$\text{Longitudinal strain} = \frac{l}{L} \ldots \ldots \ldots \ldots (1)$$

$$\text{and} \quad \text{Normal stress} = \frac{F}{A} = \frac{mg}{\pi r^2} \ldots \ldots \ldots \ldots (2)$$

where, m is the mass of the load, g is the acceleration due to gravity and r is the radius of the wire.

$$\text{Therefore,} \quad Y = \frac{Normal\ stress}{Longitudinal\ strain} = \frac{\frac{F}{A}}{\frac{l}{L}} = \frac{mgL}{\pi r^2 l} \ldots \ldots \ldots \ldots (3)$$

As stress is force per unit area, it's CGS unit is dyne/cm^2. A strain is a ratio and has no dimension. Young modulus is, therefore, expressed in the same unit of stress. The dimensional formula for Young's modulus is $ML^{-1}T^{-2}$.

Procedures:

1. At first unzip "**Young's Modulus_vle (zipped)**" File. Click on the executable file "**Youngs Modulus_vle**" then a window will open as shown in Fig. 1.

2. Select the material of the wire whose Young's modulus you want to determine by choosing steel from the rectangle box on the top left (Arrow-1) of Fig. 1.
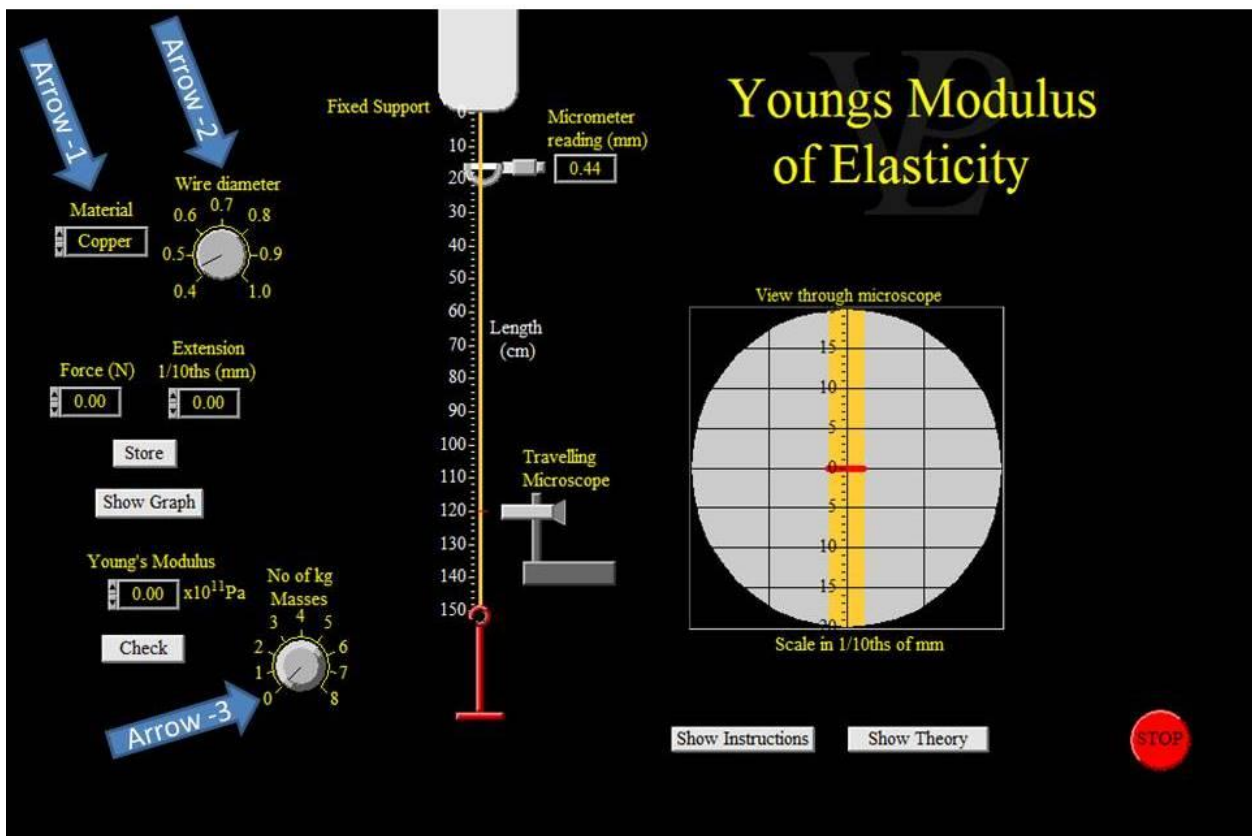

Fig. 1

3. Adjust the diameter (0.6 mm) of the steel wire using the circular knob on the top (Arrow-2) as shown in Fig. 1. Keep the material and diameter of the wire unchanged throughout your experiment.

4. Start with the wire totally unloaded but with just the hanger to keep the wire straight (this can be considered as dead load).

5. Add a 1 kg of mass using the circular knob near the bottom of the screen (Arrow-3) as indicated in Fig. 1. Record the extension of the wire as seen through the microscope. You have to wait for a few seconds until the oscillation of the red pointer in the field of view of the microscope is stopped. Remember that the microscope scale in 1/10ths of mm, i.e., its 1 division equal to 0.1 mm.

6. Repeat step 5 by increasing load one by one up to 8 kg. These are reading with the loads increasing on the hanger.

7. Take out the load one by one from the hanger and obtain another set of readings for loads decreasing.

8. Each time measure the length of the experimental wire from the point of suspension to the point where the travelling microscope is fixed due to the measurement of the extension.

9. Calculate the cross-sectional area of the wire from the diameter measured by the micrometer (Screw gauge).

10. Draw the mean elongation versus load graph with elongation along the ordinate and load along the abscissa.

11. Calculate the slope/gradient of the graph and then Young's modulus of the wire using the above data and the working formula (Eq. 3).
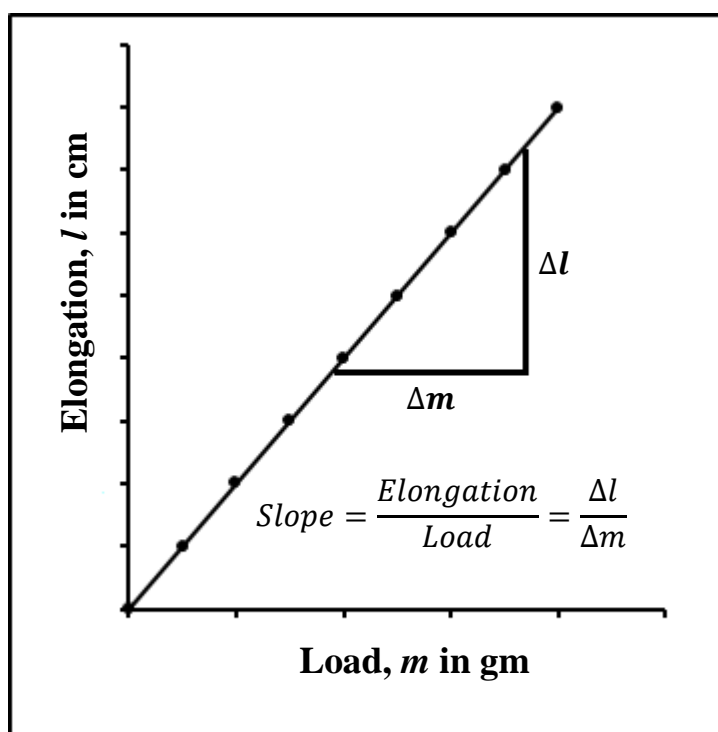
Data Collections:

(A) Diameter of the wire, $d = \ldots$ cm

Therefore, radius of the wire, $r = \dfrac{d}{2} = \ldots\ldots\ldots$ cm

Area of cross section of the wire, $\pi r^2 = \ldots\ldots\ldots$ cm^2

(B) Initial length of the wire = 120 cm

(C) Reading for elongation versus load

Table 1: Reading for measuring the mean elongation

No. of observation	Additional load on the hanger m (gm)	Reading for the elongation l (cm)		Mean elongation l (cm)
		Load increasing	Load decreasing	
1				
2				
3				
4				
5				
6				
7				
8				

(D) Plot a graph of elongation vs. load

Calculation:

$$Young's\ modulus, Y = \frac{mgL}{\pi r^2 l} = \frac{gL}{\pi r^2}\frac{m}{l} = \frac{gL}{\pi r^2}\frac{1}{Slope}\ dyne/cm^2$$

Result:

$$Young's\ modulus, Y = \ldots\ldots dyne/cm^2$$

$$= \ldots\ldots Newton/m^2$$

Error analysis:

$$\%\ of\ error = \frac{|Measured\ value - Standard\ value|}{Standard\ value} \times 100\% = \ldots\%$$

Discussion:

Based on your understanding by conducting this experiment, answer the following questions:

1) Why it is necessary to wait for a while before taking the reading after putting a load on the hanger or removing a load from the hanger?
2) If the length and the diameter of the wire are changed, will there be any change in the value of Young's modulus of that wire?
3) On what factors do the value of Young's modulus depends?
4) Explain briefly the effect of temperature on Young's modulus.
5) Why steel is more elastic than rubber?
6) Mention some uses of Young's modulus in our practical life.