

## TO DETERMINE YOUNG'S MODULUS OF ELASTICITY OF THE MATERIAL OF A BAR BY THE METHOD OF FLEXURE

**Aim:** To determine the Young's modulus of elasticity of the given material.

**Apparatus:** meter scale, weights, screw gauge, spherometer and slide caliper

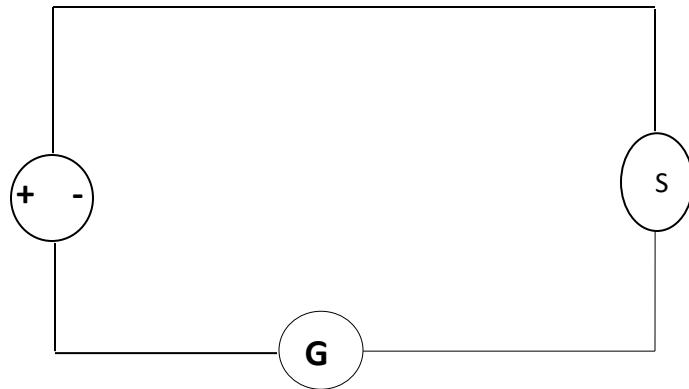
**Theory:** If a low-weight bar of breadth  $b$  and depth  $d$  is placed horizontally on two knife-edges separated by a distance  $L$ , and a load of mass  $m$ , applied at the mid-point of the bar, produces a depression  $l$  of the bar, then Young's modulus  $Y$  of the material of the bar is given by

$$Y = \frac{gL^3}{4bd^3} \frac{m}{l} \quad (1)$$

where  $g$  is the acceleration due to gravity. This is the working formula of the experiment, and is valid so long as the slope of the bar at any point with respect to the unstrained position is much less than unity. Here  $Y$  is determined by measuring the quantities  $b$ ,  $d$ ,  $L$  and the mean depression  $l$  corresponding to a load  $m$ . If  $b$ ,  $d$ ,  $L$  and  $l$  are measured in cm,  $m$  in gm,  $g$  is expressed in cm/sec<sup>2</sup>, and then  $Y$  is obtained in dyne/cm<sup>2</sup>.

### Procedure:

- (i) Measure the length of the given bar with a meter scale and place the centre of the bar at the middle point of the two supports fixed to the table.
- (ii) Place rectangular hook cum hanger at the centre of the scale. Place the spherometer such that the screw of the spherometer is on top of the rectangular hook cum hanger.
- (iii) Make the electrical connections as shown in the Figure (1) by connecting the power supply, spherometer and galvanometer.
- (iv) Switch on the power supply, adjust the circular scale such that the screw of the spherometer (S) touches the rectangular hook, indicating deflection in the Galvanometer (G).
- (v) Take the initial reading on the spherometer.
- (vi) Hang a weight to the hook and then you notice that galvanometer reading come back to zero (why?). Again adjust the spherometer such that screw touches the hook and galvanometer deflects. Take the depression of the bar reading corresponding the weight hung.
- (vii) Continue the same procedure for all the weights. Avoid back lash error while using the spherometer.
- (viii) Repeat the experiment once again with all the weights.



**Figure 1:** Schematic diagram of electrical connections

- (ix) Determine the vernier constant (least count) of the slide callipers and measure with it the breadth  $b$  of the bar at three different places. Calculate the mean breadth of the bar. Note the zero error, if any, of the slide callipers and find the correct value of  $b$ .
- (x) Determine the least count of the screw gauge and measure the depth  $d$  of the bar at a number of places along the length of the bar. Find the mean value. Note the zero error, if any, of the screw gauge and obtain the correct value of  $d$ .
- (xi) Draw a graph with the load  $m$  in grams along the X-axis and the corresponding depression  $l$  in cm along the Y-axis and determine the value of  $Y$ .

**Experimental Results:**

**Table-1**

Least count of spherometer =..... cm

| Pitch of the screw $p$ (cm) | No. of divisions $n$ on the circular scale | Least count = $p/n$ (cm) |
|-----------------------------|--|--------------------------|
| .....                       | .....                                      | .....                    |

**Table-2: Load-depression data for chosen length**

Distance between the knife-edges  $L = \dots \text{cm}$

| No. of obs. | Load in (kg) | spherometer reading for increasing load (cm)- first measurement |          |       | Spherometer reading for increasing load (cm)- second measurement |          |       | Mean reading (cm) | Depression $l$ (cm) |
|-------------|--------------|---|----------|-------|--|----------|-------|-------------------|---------------------|
|             |              | Main scale  | Circular | Total | Main scale   | Circular | Total |                   |                     |
| 1           | ..           | ..  | ..       | ..    | ..   | ..       | ..    | ....(a)           | 0                   |
| 2           | ..           | ..  | ..       | ..    | ..   | ..       | ..    | ....(b)           | (b) - (a)           |
| 3           | ..           | ..  | ..       | ..    | ..   | ..       | ..    | .....(c)          | (c) - (a)           |
| ..          | ..           | ..  | ..       | ..    | ..   | ..       | ..    | ...               | ...                 |
| ..          | ..           | ..  | ..       | ..    | ..   | ..       | ..    | ...               | ...                 |

To get the average  $\frac{m}{l}$ , plot load ( $m$ ) in kg versus Depression ( $l$ ) and obtain slope 's' and error in slope ' $\Delta s$ ' by straight line fit.

**Table-3: Least count (l.c.) of the slide caliper**

..... Divisions of the Vernier scale = ..... divisions of the main scale.

| Value of smallest main scale division ( $l_1$ ) | Value of smallest Vernier scale division ( $l_2 = \frac{n}{m} l_1$ ) (cm) | Least count (l.c.) = $(l_1 - l_2)$ (cm) |
|---|---|---|
| .....   | .....   | .....                                   |

**Table-4: Measurement of breadth ( $b$ ) of the bar by slide caliper**

| No. of obs. | Readings (cm) of the |         | Total reading $b$ (cm) | Mean $b$ (cm) | Zero error (cm) | Corrected $b$ (cm) |
|-------------|----------------------|---------|------------------------|---------------|-----------------|--------------------|
|             | Main scale           | Vernier |                        |               |                 |                    |
|             |                      |         |                        |               |                 |                    |

**Table-5: Least count (l.c.) of the screw gauge**

| Pitch of the screw $p$ (cm) | No. of divisions $n$ on the circular scale | Least count = $p/n$ (cm) |
|-----------------------------|--|--------------------------|
| .....                       | .....                                      | .....                    |

**Table-6: Measurement of depth ( $d$ ) of the bar by the screw gauge**

| No. of obs. | Readings (cm) of the |         | Total reading $d$ (cm) | Mean $d$ (cm) | Zero error (cm) | Correct $d$ (cm) |
|-------------|----------------------|---------|------------------------|---------------|-----------------|------------------|
|             | Main scale           | Vernier |                        |               |                 |                  |
| 1           | ...                  | ...     | ...                    | ...           | ...             | ...              |
| 2           | ...                  | ...     | ...                    | ...           | ...             | ...              |
| 3           | ...                  | ...     | ...                    | ...           | ...             | ...              |

**Discussion:**

Even though the entire scale or bar deforms by applying the stress to given bar or scale, length  $L$  in  $Y = \frac{gL^3}{4bd^3} \frac{m}{l}$  (or  $Y = \frac{gL^3}{4bd^3} s$ ) corresponds to the portion between the two knife edges but not the total length of the given bar or meter scale. **Why?** Refer to supporting material.

**Computation of error:** The error in  $Y$  due to propagation of uncertainty in the measurement of  $L, b, d$  and  $s$  is given by

$$\frac{\Delta Y}{Y} = \sqrt{\left(3 \frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta b}{b}\right)^2 + \left(3 \frac{\Delta d}{d}\right)^2 + \left(\frac{\Delta s}{s}\right)^2}$$

**Precautions:** (i) In the expression for  $Y$ , both the length  $L$  between the knife-edges and the depth  $d$  of the bar occur in powers of three. But as  $d$  is much smaller than  $L$ , much care should be taken while measuring  $d$  in order to minimize the error in  $Y$ .

- (ii) Care should be taken to make the beam horizontal and to load the bar at its mid-point.
- (iii) Try to avoid parallax and back-lash errors during measurements.

**Questions:** How does the weight of the bar affect the experiment?