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# General Properties of Matter Lab
# PH29001

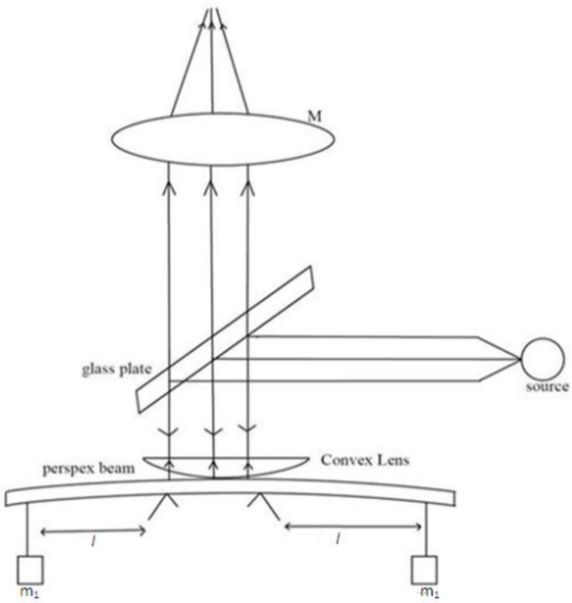
# EXPERIMENT-2

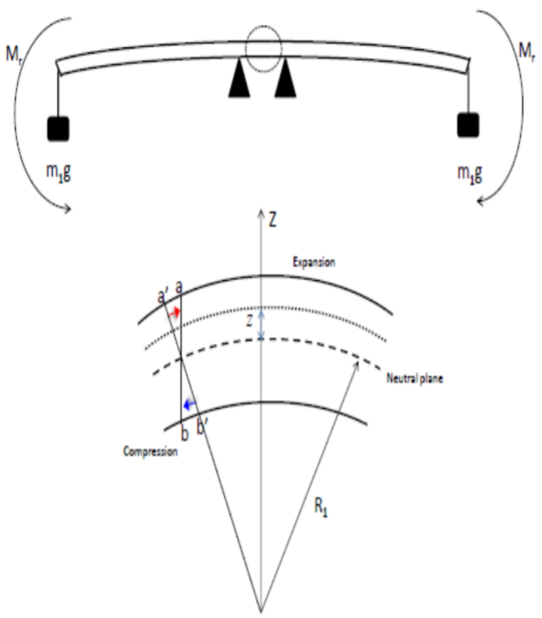
## To determine Young's modulus of a glass beam using Cornu's Method

**Aim:** To determine Young's modulus of a glass beam using Cornu's Method.

**Apparatus:** Glass beam, two knife edges, weights, spirit level, meter scale, screw gauge, travelling microscope, vernier calipers, a plano-convex lens.

**Theory**: The Newton's rings experiment is the basis of Cornu's method in which glass reflector is replaced by a glass beam whose Young's modulus is to be found. When equal weights are attached to the two ends of the beam, it results in longitudinal bending which results in a small amount of lateral bending, therefore causing lateral strain $R_2$ (upward bending perpendicular to the length of the beam). Due to this, the shape of the Newton rings will change from circular to elliptical. During bending, an extension is caused on the upper surface and compression on the lower surface, resulting in stress.



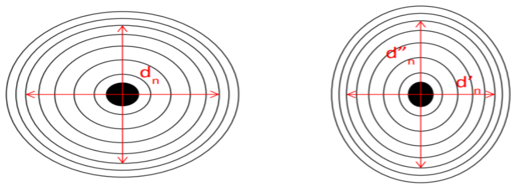

Elongation (contraction) of a plane a distance "z" above (below) the neutral plane (see fig. 4) is given by: $\varepsilon(z) = \frac{(R_1 + z)\theta - R_1\theta}{R_1\theta} = \frac{z}{R_1}$ and stress is $\boldsymbol{\sigma}(z) = Y * z/R_1$ and bending moment is -

$$M_r = 2\int_0^{h/2} \sigma(z).z\,(w.dz) = \frac{Y\,w\,h^3}{12\,R_1}$$ and $$M_r = m_1 g.L$$ . Therefore,

$$Y = \frac{12\,m_1\,g\,L\,R_1}{w\,h^3}$$

Where $m_1$=weight of the suspended body from ends of glass beam, L= distance between the knife edge and edge of bar, $R_1$=the longitudinal radius of curvature of the beam, w = breadth of the glass beam, h = thickness of glass beam.

And longitudinal bending $R_1$ - $R_1 = \frac{1}{4n\lambda}\frac{d'^2_n d^2_n}{(d^2_n - d'^2_n)}$ where $d_n$' and $d_n$ are the diameters of nth ring with mass and without mass in longitudinal direction. Similarly for $R_2$ - $R_2 = \frac{1}{4n\lambda}\frac{d''^2_n d^2_n}{(d^2_n - d''^2_n)}$ where $d_n$" and $d_n$ are the diameters of nth ring with mass and without mass in transverse direction ( $d_n' < d_n < d_n''$).




W = 0 W = $m_1g$

## Observations:

Least Count of Meter Scale = 0.1cm and temperature of the laboratory while taking the measuring the values of the parameters = 30°C

**Table-1-**

Vernier Constant (V.C.) of the Travelling microscope-

Value of 1 smallest main scale division = 0.5mm = 0.05cm
Total number of smallest divisions on Vernier Scale=50
Vernier Constant (V.C) = $0.05/50 = 0.001cm$

| Value of 1 smallest main scale division ($l_1$) (cm) | Value of 1 vernier division $l_2 = (n/m)l_1$ (cm) | Vernier constant (vc) = $(l_1 - l_2)$ = 0.001 cm & Zero error = 0 cm |
|---|---|---|
| 0.05 | 0.049 | |

**Table-2-**

Calculation of $X^2_5 - X^2_1$ for different weights-

| Sl. No. | Weight (gm) | No. of fringes (n) | Left end $D_1$ (cm) | Right end $D_2$ (cm) | Difference $= (D_1 - D_2)$ cm | $X_5^2 - X_1^2$ (in $cm^2$) |
|---|---|---|---|---|---|---|
| 01 | $W_1 = W + 550$ | 1 | 5.176 | 4.796 | $X_1 = 0.380$ | 0.546 |
| | | 5 | 5.387 | 4.556 | $X_5 = 0.831$ | |
| 02 | $W_2 = W + 600$ | 1 | 5.198 | 4.863 | $X'_1 = 0.335$ | 0.499 |
| | | 5 | 5.384 | 4.602 | $X'_5 = 0.782$ | |
| 03 | $W_3 = W + 650$ | 1 | 5.192 | 4.848 | $X''_1 = 0.344$ | 0.467 |
| | | 5 | 5.385 | 4.620 | $X''_5 = 0.765$ | |
| 04 | $W_4 = W + 700$ | 1 | 5.158 | 4.852 | $X'''_1 = 0.306$ | 0.436 |
| | | 5 | 5.371 | 4.643 | $X'''_5 = 0.728$ | |

**Table-3-**

Measurement of breadth (b) of the glass beam-

The least count of the vernier = 0.02cm

| No. of obs. | Readings (cm) of the Main scale | Vernier | Total (cm) | Mean breadth $b$ (cm) | Mean breadth $b$ (m) |
|---|---|---|---|---|---|
| 1 | 3.0 | 6 | 3.12 | 3.09 | 0.0309 |
| 2 | 3.1 | 0 | 3.10 | | |
| 3 | 3.0 | 2 | 3.04 | | |

**Table-4-**

Least count (L.C.) of the screw gauge-

Pitch of the screw (p) = 0.05cm

Total number of divisions on Circular Scale (n)=50

Least count (L.C) = $0.05/50 = 0.001cm$

| Pitch of the screw $p$ (cm) | No. of divisions n on the circular scale | Least count = $p$/n = 0.001 cm & Zero error = 0 cm |
|---|---|---|
| 0.05 | 50 | |

**Table-5-**

Measurement of thickness (t) of the glass beam by the screw gauge-

| No. of obs. | Readings (mm) of the | | Total $d$ (mm) | Mean $t$ (mm) | Mean $t$ (m) |
|---|---|---|---|---|---|
| | Main scale | Vernier | | | |
| 1 | 4.0 | 02 | 4.02 | 3.797 | 0.00379 |
| 2 | 3.0 | 61 | 3.61 | | |
| 3 | 3.0 | 76 | 3.76 | | |

**TABLE-6-**

Distance between the knife edge and the hanger point-

Least count of the vernier callipers = 0.02cm

| Sl. No. | $K_1H_1\,(cm)$ | $K_2H_2\,(cm)$ | $d = \frac{K_1H_1 + K_2H_2}{2}\,cm$ | Mean d (m) |
|---|---|---|---|---|
| 01 | 11.48 | 11.42 | 11.45 | 0.1145 |
| 02 | 11.46 | 11.44 | 11.45 | |
| 03 | 11.48 | 11.41 | 11.44 | |

**Table-7-**

Calculation of $\frac{1}{R}\,m^{-1}$

$$\frac{1}{R} = \frac{4\lambda(n-1)}{X_5^2 - X_1^2}$$

| Sl. No. | Weight $W_i$ | No. of fringe (n) | λ in (m) | $\frac{1}{R_i}\left(m^{-1}\right);\, when\, i = 1,2,3,4$ |
|---|---|---|---|---|
| 01 | $W_1 = W + 550; i = 1$ | 5 | $589{\times}10^{-9}$ m | 0.1726007232 |
| 02 | $W_2 = W + 600; i = 2$ | 5 | $589{\times}10^{-9}$ m | 0.1888577154 |
| 03 | $W_3 = W + 650; i = 3$ | 5 | $589{\times}10^{-9}$ m | 0.2017987152 |
| 04 | $W_4 = W + 700; i = 4$ | 5 | $589{\times}10^{-9}$ m | 0.216146789 |

**Table-8-**

Calculation of Young's modulus of glass-

$$Y = \frac{12d(W_j - W_i)}{bt^3\left(\frac{1}{R_j} - \frac{1}{R_i}\right)}$$

| Sl. No. | $i$ | $j$ | $\left(\frac{1}{R_j} - \frac{1}{R_i}\right) m^{-1}$ | $(W_j - W_i)\ kg$ | $Y = \frac{12d(W_j - W_i)}{bt^3\left(\frac{1}{R_j} - \frac{1}{R_i}\right)}\ \frac{N}{m^2}$ |
|---|---|---|---|---|---|
| 01 | 1 | 2 | 0.0162569922 | 0.05 | 24.64389 x $10^9$ |
| 02 | 2 | 3 | 0.0129409998 | 0.05 | 30.95864 x $10^9$ |
| 03 | 3 | 4 | 0.0143480738 | 0.05 | 27.92261 x $10^9$ |

Mean of Y = 27.84176 x $10^9$ $N/m^2$

**Analysis-**

From table-8, clearly, the Young's Modulus of the glass beam is $27.84176\times\ 10^9 N/m^2$ using the Cornu's Method.

**Error Analysis-**

Working formula-

$$Y = \frac{12d(W_j - W_i)}{bt^3\left(\frac{1}{R_j} - \frac{1}{R_i}\right)} = \frac{12d(W_1 - W_2)}{bt^3\left(\frac{1}{R_1} - \frac{1}{R_2}\right)} = \frac{12d(W_2 - W_1)R_2R_1}{bt^3(R_2 - R_1)}$$

$$\Rightarrow \frac{\Delta Y}{Y} = \frac{\Delta b}{b} + \frac{\Delta d}{d} + 3\frac{\Delta t}{t} + \frac{\Delta R}{R}$$

$$\frac{\Delta Y}{Y} = \frac{3\Delta t}{t} + \frac{\Delta b}{b} + \frac{\Delta \mathrm{d}}{d} + \frac{1}{R_2 - R_1} \cdot \left(\frac{\Delta R_2}{R_2} - \frac{\Delta R_1}{R_1}\right)$$

$\Delta t = 0.001cm, t = 0.379cm, \Delta b = 0.02cm, b = 3.087cm$

$\Delta d = 0.02\mathrm{cm}, \mathrm{d}{=}11.45\mathrm{cm}, \Delta R_2 = \Delta R_1 = 0.001cm$

$R_1 = 579.374cm, R_2 = 495.543cm$

$$\frac{\Delta Y}{Y} = \frac{3(0.001)}{0.379} + \frac{0.02}{3.087} + \frac{0.02}{11.45} + \frac{1}{495.543 - 579.374} \cdot \left(\frac{0.001}{495.543} - \frac{0.001}{579.374}\right)$$

$$\frac{\Delta Y}{Y} = 0.01614$$

$$\Delta Y = Y \times 0.01614 = 27.84176 \times 10^9 \times 0.01614 = 0.449 \times 10^9$$

$$\frac{\Delta Y}{Y} \times 100 = 1.61\%$$

The maximum percentage error in Y ( Young's Modulus) is 1.61%

Therefore, Y= $(27.84 \ \pm 1.61) \times 10^9 \ N/m^2$

**Results-**

1. Therefore, the Young's Modulus of the glass beam by Cornu's Method is $(27.84 \ \pm 1.61) \times 10^9 \ N/m^2$
2. The maximum percentage error in Young's Modulus (Y) is 1.61%.

**Precautions-**

1. To reduce statistical error in measurements, at least 3-5 readings must be taken.
2. The shape of the fringes must be regular. In case the shape is irregular adjust the glass plate slowly. Glass plates should be optically plane and clean.
3. The temperature of the laboratory where the experiment is being performed must be noted as the few parameters of young's modulus are temperature-dependent.
4. Care should be taken to make the beam horizontal. The glass beam must be placed symmetrically on the knife edges. Knife edges should be sharp.
5. The Travelling microscope must be placed perfectly flat using a spirit level. The load on the beam should not exceed the elastic limit of the beam.
6. An instrument available in the laboratory with the least vernier constant (or least count) must be chosen to minimise the maximum error in Young's Modulus measurement of a parameter whose dimensions are very less (i.e, less than 1), especially when the parameter has a power raised to it, in the formula.
7. After adding a load to the hanger, reading must be taken after few minutes. Adding weights should be done gently.
8. Parallax and back-lash errors during measurement must be avoided.
9. Zero error must be noted in the measuring instruments.
10. The experimental glass beam should not touch the wooden stand.

**Discussions-**

1. To measure $t$, we must use a screw gauge instead of a slide caliper as the least count of slide caliper is 0.01cm and that of the screw gauge is 0.001cm. This is done to minimise the maximum error in the measurement of Young's modulus as $t$ has a smaller value and has a power of 3 raised to it, and also the least count of screw gauge is less than that of a slide caliper.
2. Although slide calipers (V.C=0.01cm) have a lesser least count than a meter scale (V.C=0.1cm), they cannot be used to measure the length of the bar as its length is very large and hence the appropriate tool to be used is meter scale. Hence, an appropriate tool must be selected for measurement by considering the size and shape of the bar, the value of the object raised to a power of n (n>1), in the formula, and least count of the tool.
3. Breadth, thickness, distance of the hanger from each knife edge must be measured carefully as young's modulus of glass beam depends on these factors. Error in them can result in the inaccurate results of the young's modulus of glass beam.
4. When the temperature increases, the atomic thermal vibrations increase, and this will cause the changes of lattice potential energy and curvature of the potential energy curve, so Young's modulus will also change. And with the increase of temperature, the material will have a volume expansion. Hence, it is important to note down the temperature of the laboratory when the experiment is being performed.