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Poisson’s ratio and Young’s modulus for glass

Objective

a) To determine the Poisson’s ratio of a glass plate using Cornu’s method.

b) To determine Young’s modulus of a glass plate using Cornu’s method.

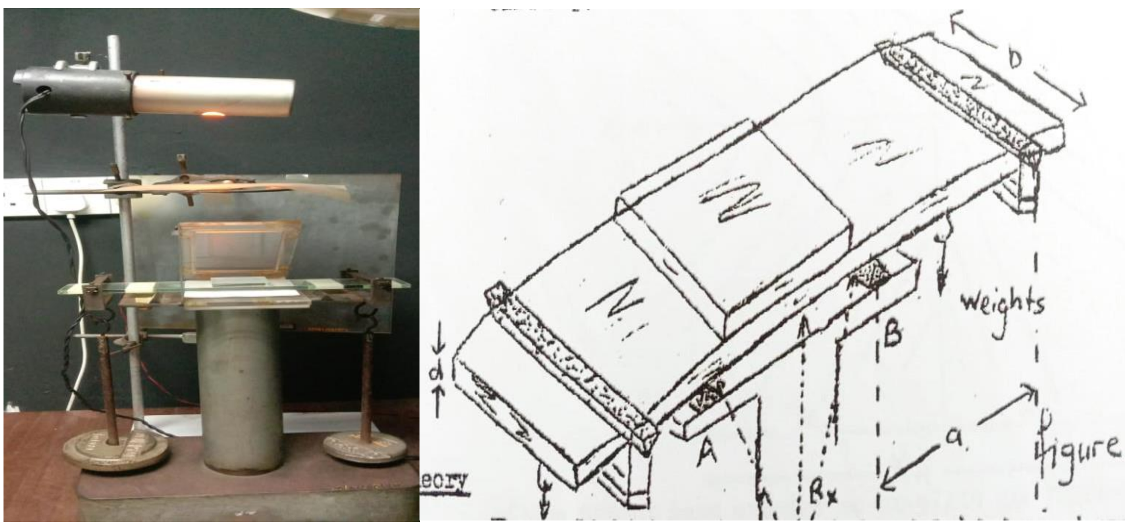

Figure 1 Experimental setup

Theoretical Background

When a light beam is supported and loaded, as shown in Figure 1 above, the portion between the knife edges A and B is bent, in the plane of the diagram, into the arch of a circle with a radius R_x, say. Bending occurs also in the plane at right angles to this, the corresponding radius being R_y, as shown in Figure 2.

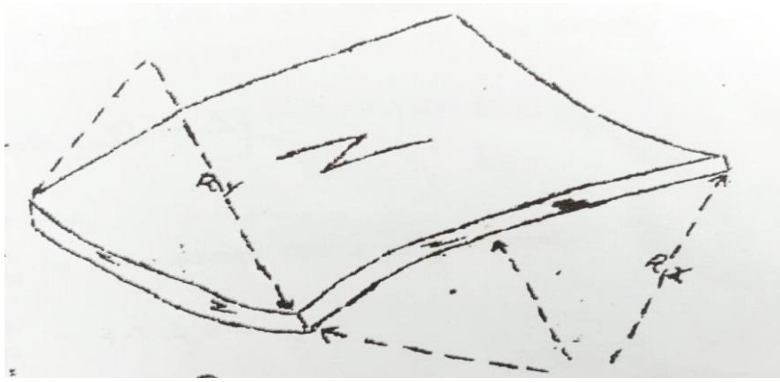

Figure 2 Radii of horizontal and vertical arcs R_x and R_y

It can be shown that Poisson's ratio for the beam is given by:

$$\sigma = R_x / R_y \quad \text{.......} \quad (1)$$

and the Young's Modulus, E, is:

$$\frac{EI}{R_x} = mga \quad \text{.......} \quad (2)$$

I is the "moment of inertia" of a beam cross-section, more strictly, the quadratic moment, or the second areal moment of the cross-section, with respect to the neutral line. From a beam of rectangular cross-section, breadth b, and thickness d, $I = bd^3/12$ (Smith page 347) m is the mass suspended from each end of the beam, and a is the distance between the point of application of the load and the adjacent supporting knife. Hence, both E and σ can be determined from the measurement of the dimensions of the beam and the longitudinal and transverse radii of curvature, R_x and R_y.

In this experiment R_x and R_y are deduced from the observation of the interference fringes produced in the air films between the upper surface of the beam and the lower surface of a flat glass plate that rests on the beam. Suppose the adjacent surface of the unbent beam and the cover plate are perfectly flat. In that case, the fringes are hyperbolic, as shown in Figure 3, and for any bright fringe:

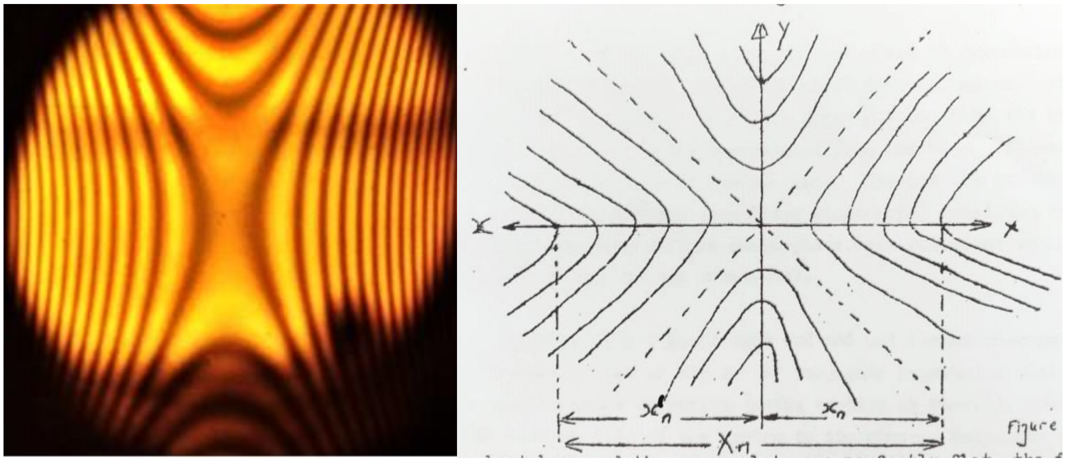

Figure 3 Hyperbolic fringes observed via telescope and schematic

$$\frac{X_n^2}{2R_x} - \frac{Y_n^2}{2R_y} = \left[\frac{(2n-1)\lambda}{4} - \Delta\right]$$

where n is an integer, λ is the wavelength of the light illuminating the system, and Δ is the thickness of the air gap at the center of the fringes. When $y = 0$, we have for the vertices of the bright fringes:

$$X_n^2 = 2R_x\left[\frac{(2n-1)\lambda}{4} - \Delta\right]$$

and hence $X_n^2 = 4\lambda R_x n - c_x$ …………………………………………………………… (3)

where $X_n = x_n - x'_n$ and c_x is a constant for a given load.

Similarly, $Y_n^2 = 4\lambda R_y n - c_y$ ……………………………………………………………(4)

Graphs of X_n^2 and Y_n^2 against n, for a fixed load should, therefore, be straight lines whose slopes R_x and R_y can be determined. The origin of n is, of course, arbitrary.

Suppose the top surface of the beam, or the lower face of the cover plate, is not initially flat. In that case, this treatment has to be modified since the measured radii are now not those produced by applying the load alone. Since distortions due to mechanical imperfections can take any form, giving a general treatment does not seem feasible.

Figure 4 Stage telescope in horizontal and vertical position

Apparatus

1. Plane glass beam.
2. Square shape glass plate
3. Stage telescope fitted with XY movable micrometer.
4. A vertical stand fitted with adjustable knife edges.
5. Sodium lamp with power supply.
6. Slide caliper and screw gauge.
7. Hangers and loads.

Procedure

1. Measure the breadth, b, and the thickness d of the glass beam using a vernier caliper and screw gauge. Take at least three readings to minimize error.
2. Clean the glass beam carefully and place it symmetrically over the supporting knife edges on the provided marks, as shown in Figure 1.
3. Place the hangers for the weight at each end on the provided marks as indicated on the glass beam (see Figure 1).
4. Place the square-shaped glass plate on the center of the glass beam.
5. Illuminate the system with the sodium lamp placed above the setup ($\lambda_{Na} = 589.3$ nm).
6. Adjust the beam and glass plate so that the fringes can be observed, as shown in Figure 3.

7. Focus the telescope and adjust the beam and plate so that the fringes (reflected on a glass plate placed at 45° to the horizontal) are symmetrical on both sides of the horizontal cross-wire and tangential to the vertical cross-wire.
8. Turn the micrometer screw attached to the telescope along the X direction of every transverse fringe on both sides to measure the longitudinal position (x); see Figure 4 (left).
9. Adjust the fringe position and telescope in such a way that at least five fringes are visible on either side from the center.
10. Take readings for about five fringes on each side (x'_n) and (x_n) starting from the extreme left-hand position (x'_5) and move to the right side up to (x_5) to avoid backlash errors.
11. Tabulate the reading for the X- X direction in Table 1.
12. Similarly, repeat the procedure in the Y direction of longitudinal fringes by standing the telescope in a transverse direction see Figure 4 (right).
13. Records the Y reading by reproducing Table 1 for the Y direction.
14. Repeat the experiment 3, 4, 5, and 6 Kg weight at each end.
15. Plot a graph of X_n^2 against n and Y_n^2 against n for each load and use Equation (3) and (4) the slopes to find the values of R_x and R_y.

Table 1

n	$x_{n'}$	x_n	$x_{n'} - x_n = X_n$	X_n^2
5				
4				
3				
2				
1				

Reference

1. H.G. Jerrad and D.B McNeil. Theoretical and Experimental Physics.
2. C.J. Smith. The General Properties of Matter, 2nd edition.
3. J.E. Calthrop. Advanced Experiments in Practical Physics.