EXPERIMENTAL EXAMINATION

Experimental problem 1

Deflection of a laser beam. Determining the refractive index.

When a light ray crosses a transparent rectangular block, refraction occurs at entry and exit. As readily seen, the emerging ray is parallel to the incident ray, as in figure 1.

The lateral displacement *d* between the rays can be expressed in terms of the angle of incidence, ε, the block thickness *L*, and the refractive index *n*. The exact expression for *d* is rather complicated, but for small incidence angles one may use approximations of the form:

$$\text{sen}\ \varepsilon \approx \varepsilon,$$

which gives: $d \approx L \dfrac{n-1}{n} \varepsilon$, (1)

so *d* is approximately proportional to ε.

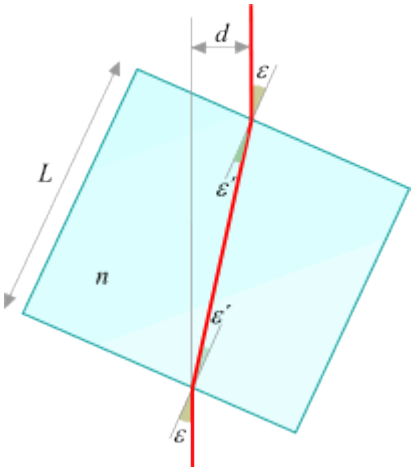


Fig. 1

The apparatus measures *d* as a function of ε. From suitable measurements of *d* and ε, determine:

a. The largest incidence angle $\varepsilon_{máx.}$ for which approximation (1) holds experimentally within the measurement precision.

b. The refractive index *n* of the material of the block.

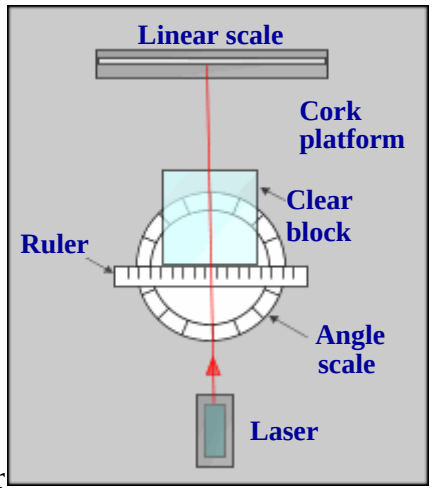


Fig. 2

Suggestions:

1. Before measuring, align the apparatus so the laser beam follows the angular scale centreline and strikes the centre of the linear scale perpendicularly, as in fig. 2.

2. Use the pins as markers when aligning; once aligned, use them to fix the laser and linear scale to the cork base.

3. The ruler can help set the incidence angle accurately: place it on the angular scale at the desired angle and rest the block against its side.

CAUTION: Never allow the laser beam to enter an eye directly: it can burn the retina.

Experimental examination 2

Mass-spring system. Dependence on the number of coils.

A helical spring stiffness k depends on its number of coils n. Assume a dependence of the form:

$$k = k_1 n^p, \qquad (1)$$

where p is a constant and k_1 is the stiffness of one coil.

If a mass M is suspended and set oscillating vertically, the period is:

$$T = 2\pi\sqrt{\frac{M + \alpha m}{k}}, \qquad (2)$$

Here m is the mass of the selected spring portion, and α is a positive constant below one. Measure for several coil numbers, verify (1), and find k_1, p, M and α.

The following equipment is provided:

- A spring with 13,8 coils per centimetre when closed (horizontal spring). Each coil has mass $1{,}656 \times 10^{-4}$ kg.
- A graduated vertical stand with a metal bracket at the top for suspending the desired length of spring.
- A lead ball of unknown mass M and an iron nut of mass M', marked in grams on one face.
- A digital stopwatch and a plastic ruler.

1. Take the measurements needed to complete the attached Table I:
   a. With the spring horizontal, select a length L_o (20, 18,....6 cm) and suspend it from the stand.
   b. Suspend mass M and record the lower spring pointer reading L.
   c. Add nut M', read the new pointer position L', and enter in Table I the length increase ΔL $\Delta = L' - L$.

d. Remove the nut, leaving only the ball suspended, and measure the system oscillation period T.

Use Table II to tabulate quantities derived from these measurements that you need for later calculations and graphs.

2. Find the spring stiffness k for each length L_o.
3. Check that k depends on n as in (1), and determine the constant p.
4. Using p, determine k_1.
5. Describe in detail how you measured the oscillation period T, and give a justified estimate of its uncertainty (error).
6. Determine M and α.