XVI Ibero-American Physics Olympiad
ECUADOR 2011
Experimental examination
26 September 2011 – 01 October 2011

Instructions

Read these instructions before starting the examination.

1. You have 5 hours for this examination.
2. The examination consists of a single problem.
3. Use the supplied equipment to solve the problem.
4. Do not write your name on any sheets or answer sheets except the cover sheet.
5. Number your examination pages (for example, 2/5 for the second of five sheets).
6. At the end, put the answer sheets in the envelope and submit it with this cover sheet.
7. Remember never to look directly into the laser beam.

Surname:		
Name:		
Country:		
Code:		
Sheets	Plain	Graph paper

XVI Ibero-American Physics Olympiad
ECUADOR 2011
Experimental examination
26 September 2011 – 01 October 2011

Determination of refractive index by the Pfund method

Maximum score: 20

The refractive index is one of a transparent material's most important physical properties. Several methods exist for measuring it. One method for a transparent plane-parallel plate was developed by Pfund (A. H. Pfund, J. Opt. Soc. Am. 31, 679, 1941).

In the Pfund method, a laser beam is incident normally on a transparent plate resting on a diffusely reflecting surface. Light scatters in all directions from the beam's point of incidence on this surface and reaches the upper surface of the plate at all angles from 0 to 90°.

An important phenomenon when light travels between two media is *total internal reflection*, characterised by a limiting (critical) angle. If light scattered from the bottom reaches the plate's upper surface at an incidence angle below the critical angle, part is transmitted into the air and part is reflected. If the incidence angle exceeds the critical angle, no light is transmitted.

Consequently, when viewed from above, a bright spot from the directly incident beam is surrounded by a much darker circular region (Figure 1). Its diameter is related to the plate's refractive index.

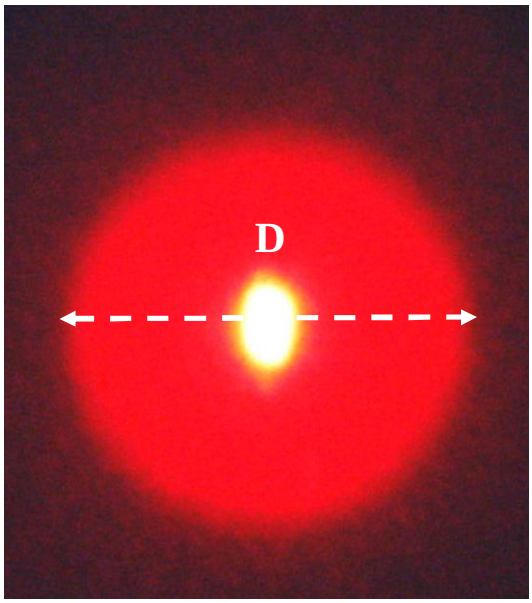


Figure 1

Snell's law is used to determine the plate's refractive index:

$n_1 sen\theta_1 = n_2 sen\theta_2$, where D is the diameter of the circle formed on the diffusing surface (paper) (Figure 1), and H is the plate thickness (Figure 2). Snell's law and the condition for total internal reflection give the following relation:

$$\frac{n_{placa}}{n_{aire}} = \sqrt{\left(\frac{4H}{D}\right)^2 + 1}$$

Measuring D for several values of H allows the plate's refractive index to be calculated from this equation.

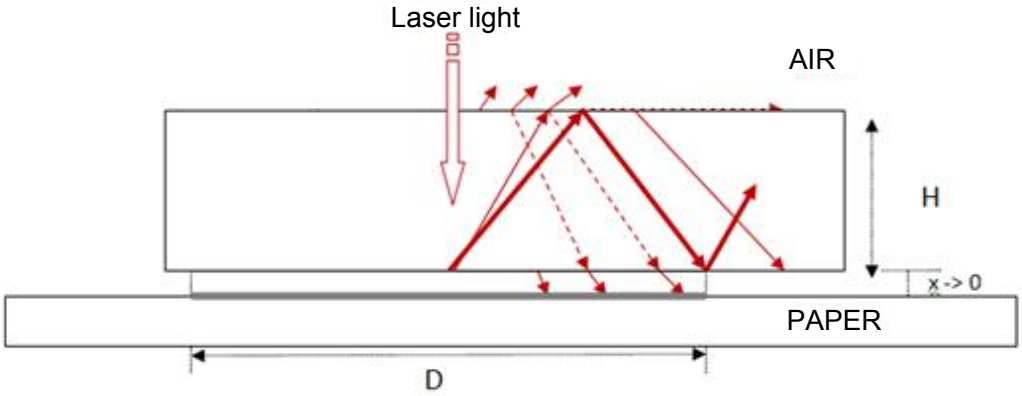


Figure 2

The following equipment is available for this experiment:

- Three glass plates of thicknesses 3,0; 5,0 and 8,0 mm
- Red laser
- Graph paper (diffusing surface)

XVI Ibero-American Physics Olympiad
ECUADOR 2011
Experimental examination
26 September 2011 – 01 October 2011

Tasks

For the following tasks, take the refractive index of air as 1,0.

1. From measurements of the three individual plates, determine the glass refractive index and estimate its uncertainty. **(6 points)**

2. Measure the diameters D with the 5,0 mm and 3,0 mm plates stacked in that order and in reverse order, without wetting the contact surface. Explain your results. **(2 points)**

3. Repeat the diameter measurements D with the 5,0 mm and 3,0 mm plates in both orders, wetting their contact surface. Explain your results. **(2 points)**

4. Compare D for the 8,0 mm plate with D for the 5,0 mm and 3,0 mm plates combined with a wetted contact surface. Explain your results. **(2 points)**

5. Determine the glass refractive index and its uncertainty from measurements of all three plates and their combinations, wetting the contact surfaces. (6 points)

6. Compare the results from task 5 with those from task 1. **(2 points)**