

Grzegorz F. Wojewoda
Zespół Szkół Ogólnokształcących nr 1
Bydgoszcz, Poland

Translation: Małgorzata Czarł

Measuring index of refraction

The advent of low-cost lasers, like laser-pointers or laser-levels, allows us to experimentally verify in classrooms values of refractive indices quoted in textbooks! We have prepared 2 exercises in which students can measure a value of a refractive index by themselves with use of a diffraction grating and a polarizer.

A. Measuring refractive index values with use of diffraction grating

1. Required materials

For conducting experiments you will need the following:

- laser pointer (alternatively laser level),
- diffraction grating with 200 to 500 lines per 1 mm. You can use a grating made of CD disc – see description of a [spectroscope on the HOU website](#), but making use of low-cost gratings will give better results. In Poland, we acquire such gratings from the ZamKor publishing house, <http://sklep.zamkor.pl/>.
- transparent vessel,
- two clips for hanging clothes,
- adhesive tape (the best will be an insulating tape),
- scissors,
- tracing paper (or any other semi-transparent paper),
- book (to be used as a stand for laser).

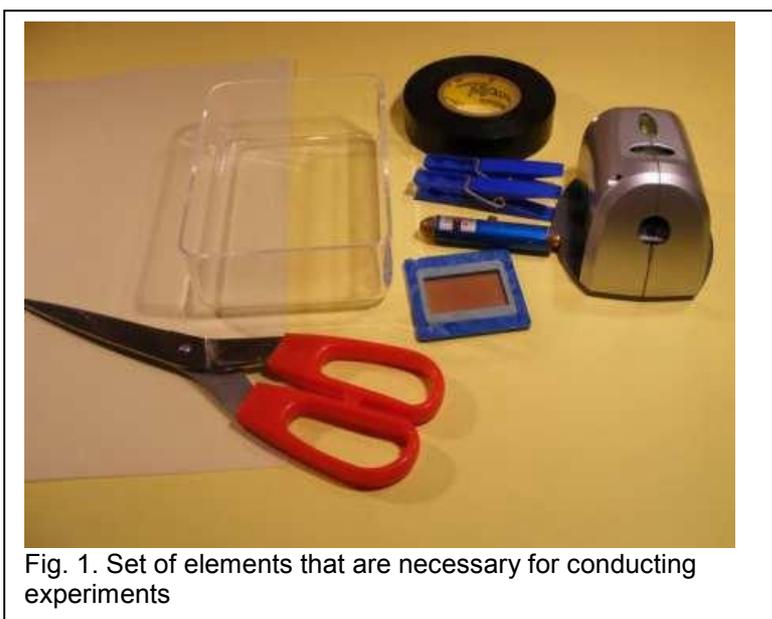


Fig. 1. Set of elements that are necessary for conducting experiments

2. Realization

Cut a part of a tracing paper with scissors and stick it to one of the external walls of a vessel. To the opposite wall stick a diffraction grating. The higher number of slits per 1mm in a grating, the bigger is the angle at which an interference pattern will be visible (one can have doubts about a possibility of comparing values of sinus and tangent of the angle at which the pattern is visible). Nonetheless, the obtained pattern shall be sharper, so defining its location will be easier.

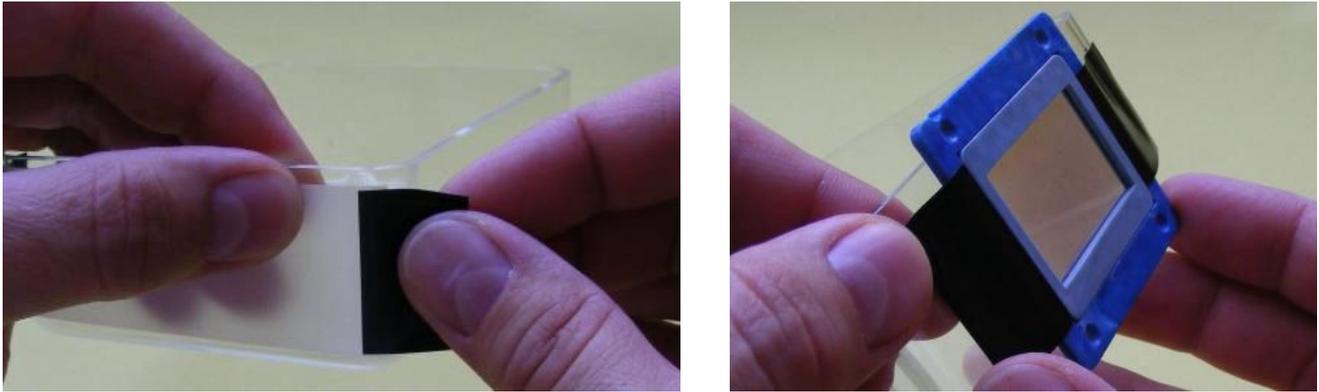


Fig. 2. Preparation of a vessel for an experiment

Into a ready-made vessel pour water or other liquid which refractive index you want to measure.

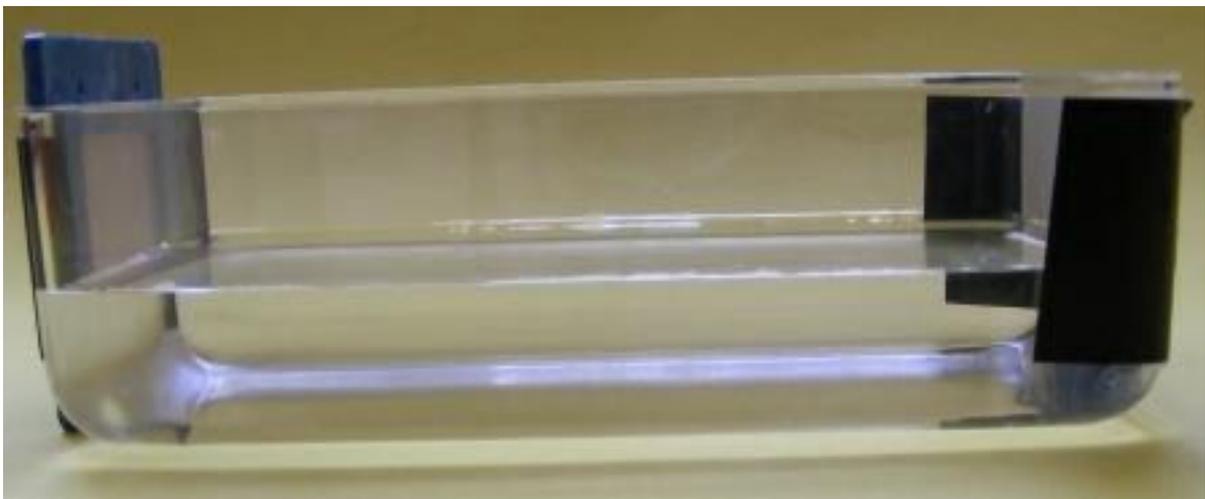


Fig. 3. Vessel filled with a liquid

Place laser in such a way to make its beam go through the liquid and mark on the screen location of a zero fringe and two fringes of the first row.



Fig. 4. Placement of laser in relation to a vessel with liquid

Change the height of laser to make its beam go above the liquid surface. Again mark location of interference fringes.



Fig. 5. New placement of laser in relation to a vessel with liquid

3. Results of an experiment

Distances between fringes of the first row marked on the screen should be shorter when laser beam goes through water than when it goes through air. It is better visible when you use a laser level (a product available in construction shops) instead of a laser pointer.

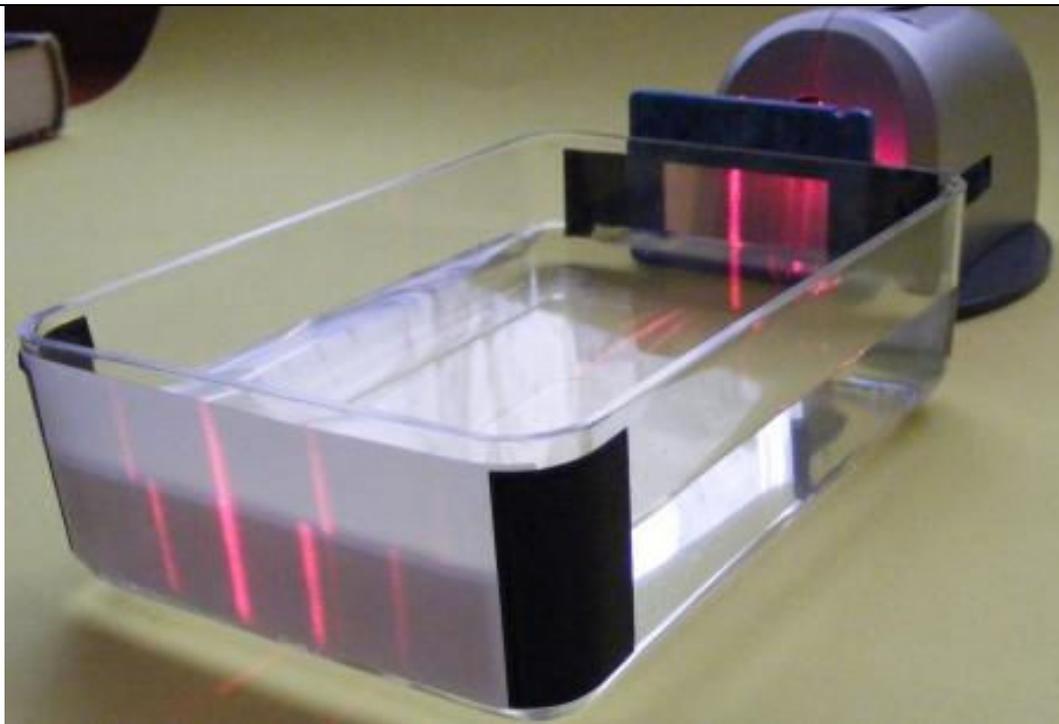


Fig. 6. Experimental system with a laser level

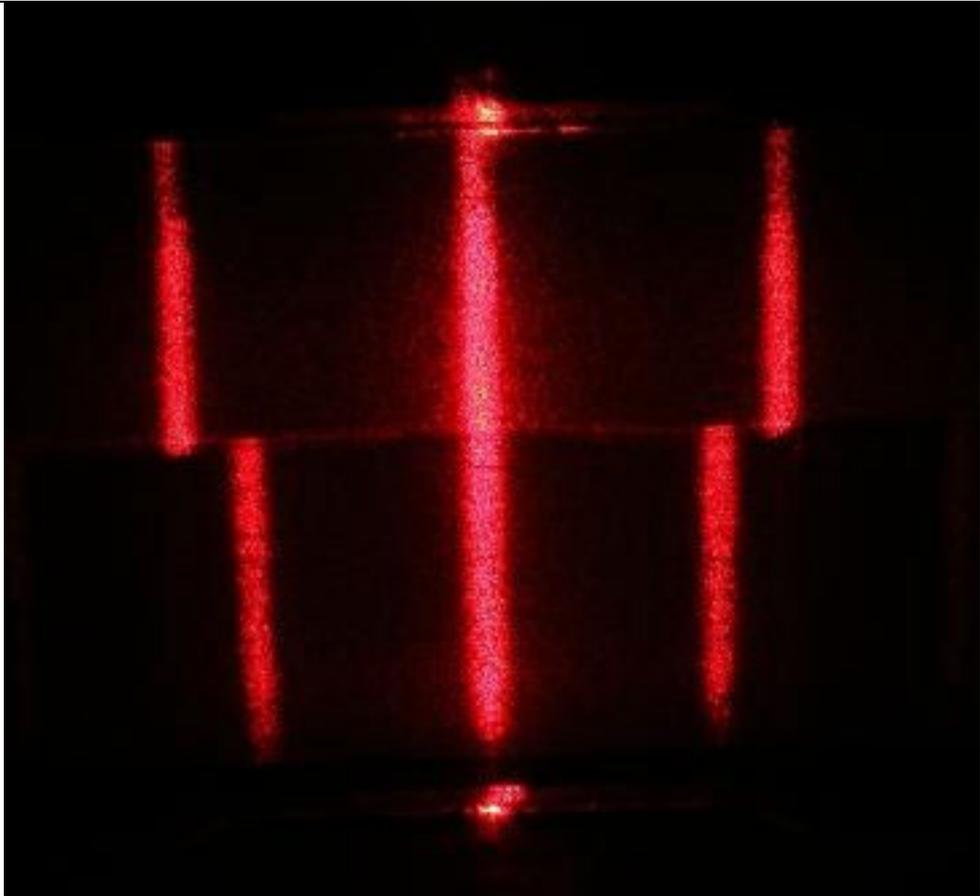
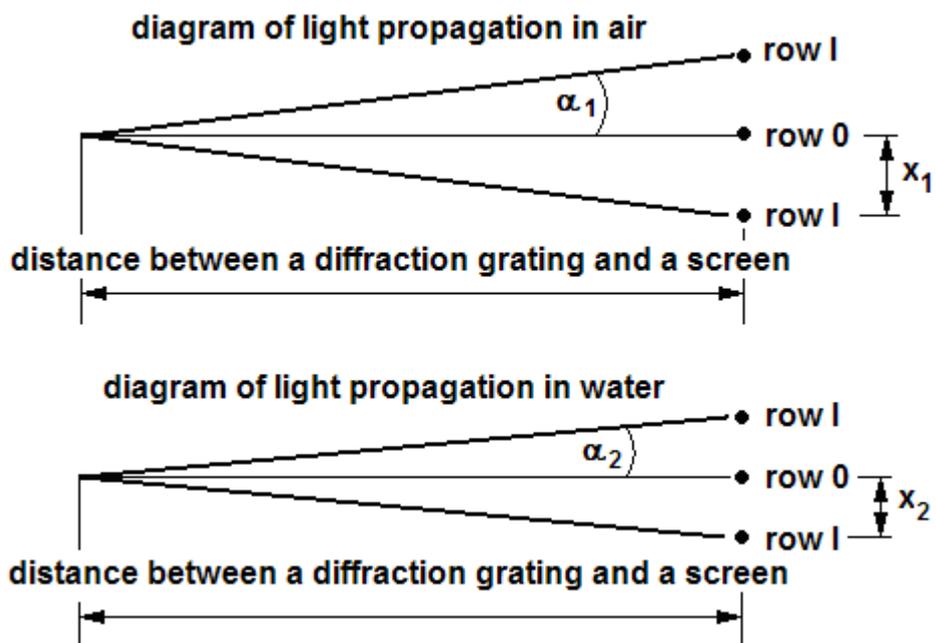


Fig. 7. Differences in interference fringes location as a result of going through water and through air

4. Elaboration of experiment results



Bright fringes of the first row meet a requirement:

$$\text{- in air: } d \cdot \sin \alpha_1 = \lambda_1$$

$$\text{- in water: } d \cdot \sin \alpha_2 = \lambda_2$$

From geometry of the experimental system:

$$\text{in air: } \operatorname{tg} \alpha_1 = \frac{x_1}{l}, \quad \text{in water: } \operatorname{tg} \alpha_2 = \frac{x_2}{l}$$

We can make use of approximation of small angles: $\sin \alpha = \operatorname{tg} \alpha$

So length of light waves:

$$\text{in air: } \lambda_1 = \frac{d \cdot x_1}{l}, \quad \text{in water: } \lambda_2 = \frac{d \cdot x_2}{l}$$

Refractive index of water relative to air:

$$n = \frac{v_p}{v_w}$$

where: $v_p = v \cdot \lambda_1$ - velocity of light in air

$v_w = v \cdot \lambda_2$ - velocity of light in water

Final value of refractive index of water relative to air:

$$n = \frac{\lambda_1}{\lambda_2} = \frac{x_1}{x_2}$$

According to our measurements, value of refractive index of water is 1.29. The value does not diverge much from values listed in tables, that is 1.3.

B. Measuring refractive index values with use of polarizer

1. Required materials

For conducting experiments you will need the following:

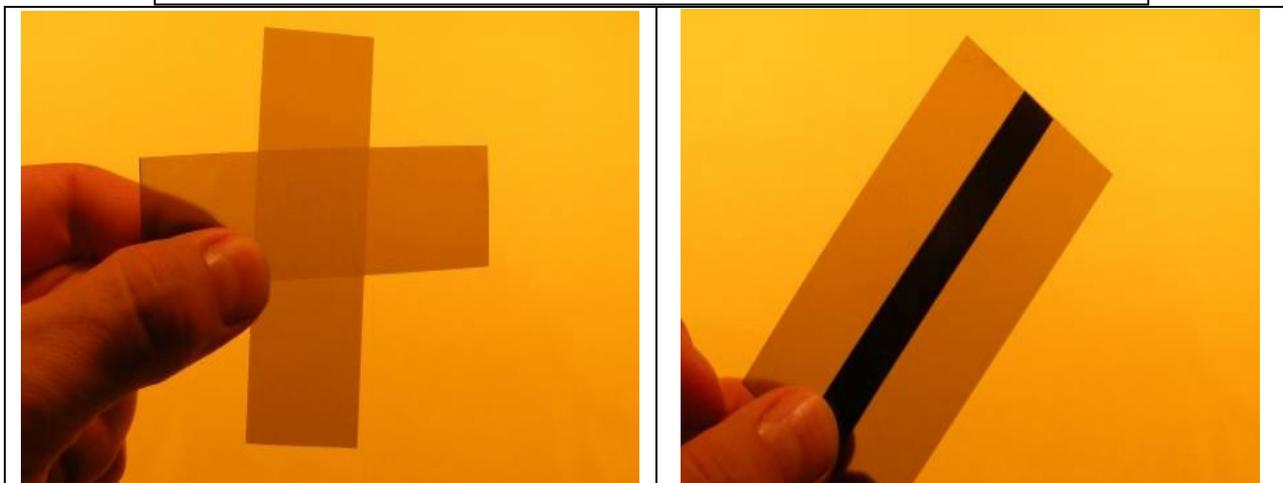
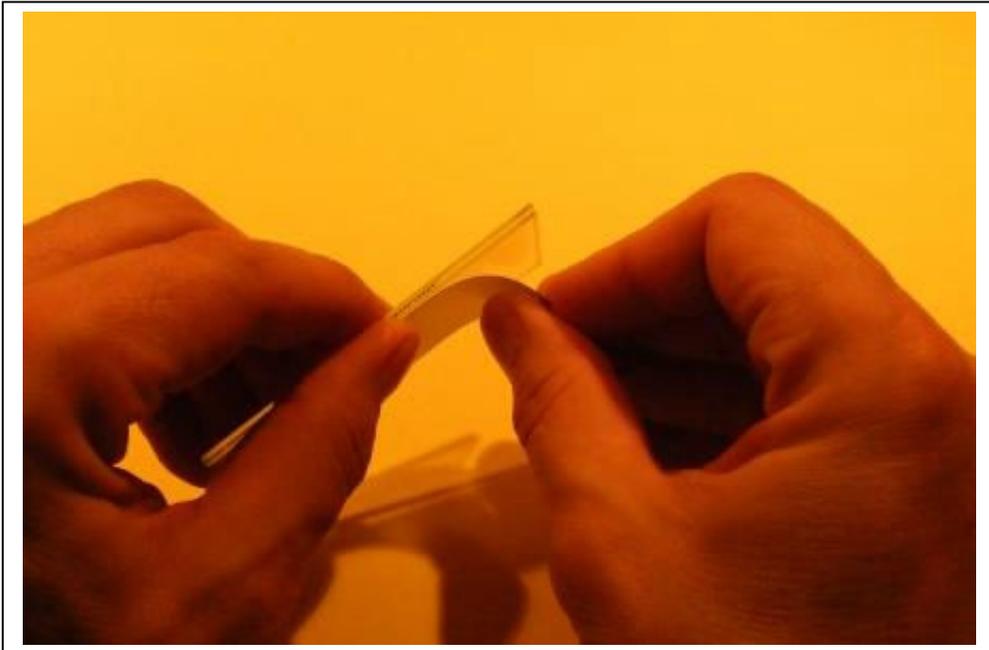
- laser pointer (alternatively laser level),
- line polarizer (you can use polarizer distributed by the ZamKor publishing house, but you can also use polarizer obtained from a calculator display or mobile phone display),
- glass pane, which refractive index you want to measure (you can use any polished dielectric),
- angle-meter,
- clips for hanging clothes,
- adhesive tape (the best will be an insulating tape),
- white paper (to be used as a screen),
- books (to be used as stands for experimental systems),
- a lot of patience ☺.



Fig. 8. Set of elements that are necessary for conducting experiments

2. Realization

If you don't have a ready-made polarizer you can obtain it from a calculator or mobile phone display (the process of obtaining polarizer will destroy a device irreparably, so it is recommended to use for that purpose a device that is definitely out of order). For that purpose you shall disassemble a display and remove from it two polarizing foils.



Photos of polarizing foils removed from a calculator display

With use of clips for clothes put a glass pane under research vertically. Put an angle-meter under the glass pane. A bottom edge of the pane shall ideally coincide with the line defined with use of the angle-meter.

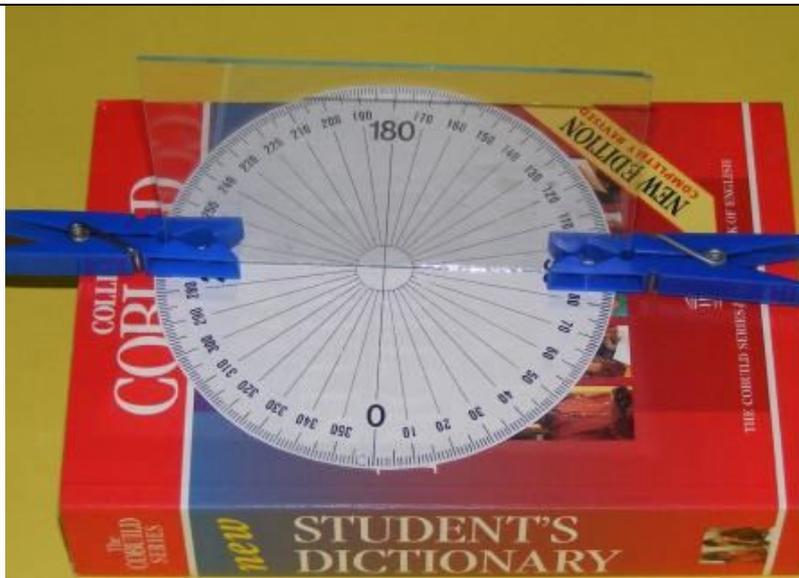


Fig. 9. Placement of glass pane on an angle-meter

Put laser on the second book and illuminate a glass pane with laser so that it was possible to see incident and reflected rays. Books are very useful for that purpose since you can change a number of pages on which optical devices are placed and precisely regulate their mutual setting.

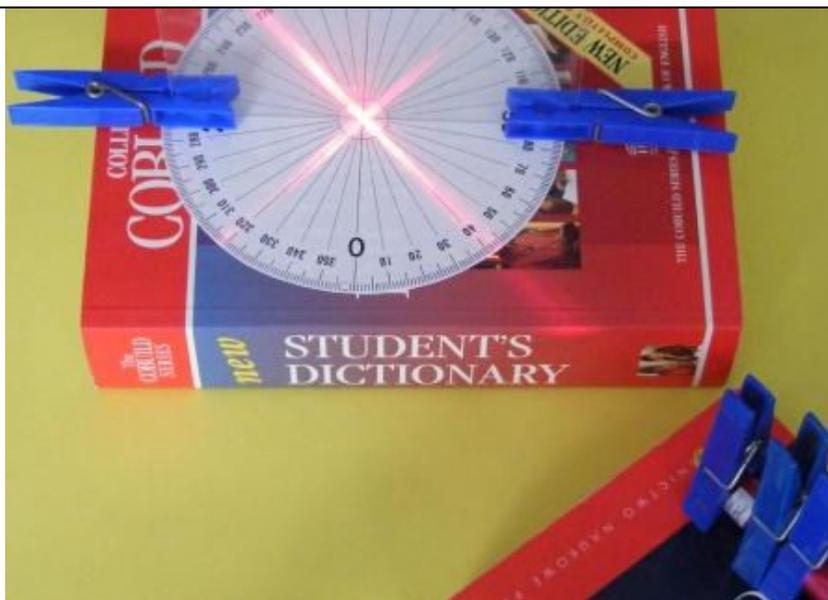


Fig. 10. Illumination of a glass pane with laser

Put a line polarizer on the way of a reflected ray. Fixture method facilitates its free rotation around the axis parallel to the ray of light reflected in the glass pane.

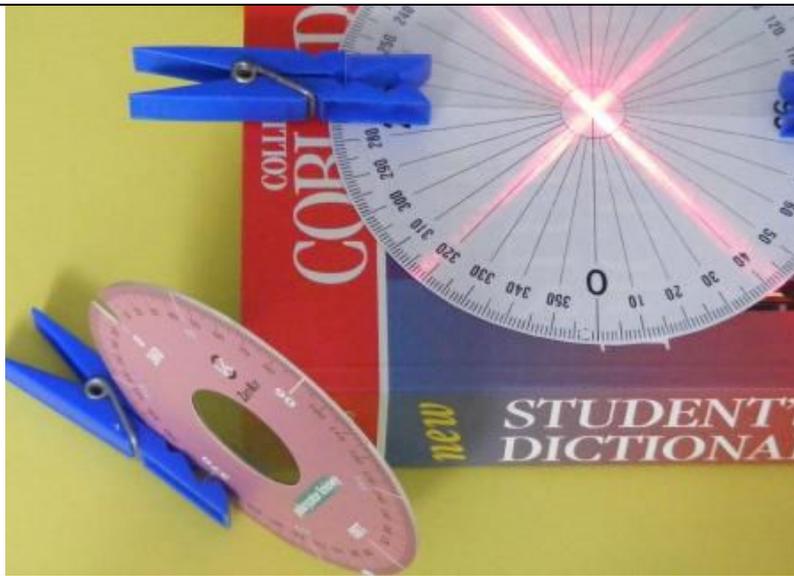


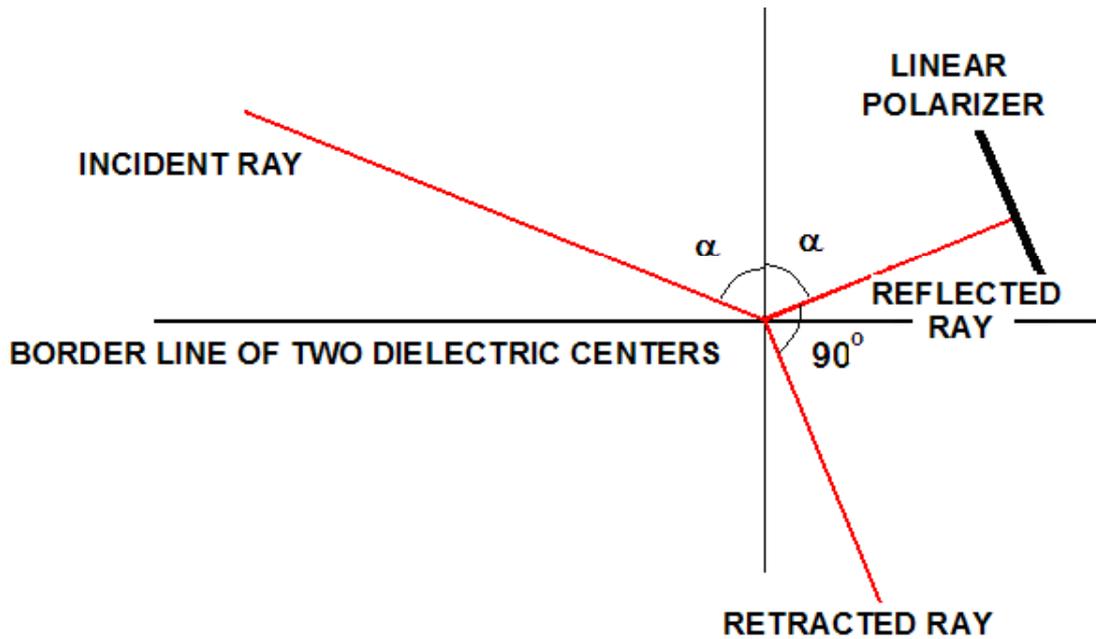
Fig. 11. Placement of polarizer in relation to the reflected ray

Light reflected from a glass pane is partly (and in a particular case fully) polarized. Our task is to obtain such a setting of an angle of light incidence to a glass pane and such a setting of a polarizer so that a reflected light did not go through a polarizer! Search of such setting requires a lot of patience and attention. When you succeed, you can assume that light reflected from a glass pane is fully polarized. An angle of incidence at which reflected light is fully polarized is a result of the experiment.



Fig. 12. Image of light reflected from a glass pane visible on a screen

3. Elaboration of experiment results



At the border line of two dielectric materials we deal with partial reflection and refraction of light. When there is an angle of 90° between a reflected and refracted ray, reflected light becomes polarized linearly. An angle of incidence which meets that requirement is known as the Brewster's angle. Relation between the Brewster's angle and refractive index is the following:

$$\operatorname{tg} \alpha = n$$

It means that in our experience we are not interested in a refracted ray, but in a reflected ray. So the thickness of dielectric from which a fully polarized ray is reflected is of no importance. Therefore, that method can be used to measure a refractive index for a non-transparent dielectric.