# 2003-2004 Physics Olympiad Preparation Program

## – University of Toronto –

## Problem Set 4: Optics

1. **Lenses can be not only round.**

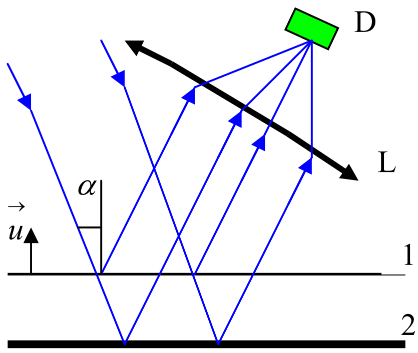
The external diameter of a thin glass tube is much greater than the diameter of the internal capillary. The index of refraction of the glass is 4/3. Through the side surface the diameter of the capillary seams to be equal to *d=2.66 mm.*
What is the real diameter of the capillary in the tube?

2. **A crooked ray.**

The index of refraction $n$ of the planet X atmosphere decreases with the altitude $h$ as $n = n_0 - \alpha h$, where $\alpha$ is a constant. The planet radius equals *R*.
At what altitude the ray of the light can propagate around the planet along the circumference?

3. **Mirrors in wave optics.**

A parallel beam of quasi-monochromatic light with wavelength $\lambda = 500nm$ falls on the system of two plane mirrors 1 and 2 with the angle of incidence $\alpha = 30^0$ (Fig.1). Partly the beam is reflected from the surface of the semi-transparent mirror 1, partly – by the stationary mirror 2. Reflected rays pass through the lens *L* to the detector *D* in the focal plane of the lens. Signal in the detector is proportional to the intensity of the received wave. What is the frequency of the signal in the detector if mirror 1 is moving upward with the speed $u = 0.01 cm/s$, as it is shown if Fig.1?




4. **Transparent barrier.**

Light is an electromagnetic wave and can be described as a propagation of alternating electric and magnetic fields that creates each other. The vectors of electric field ***E*** and magnetic field ***B*** in the wave are always perpendicular to each other and to the direction of propagation. Waves in which the electric and magnetic fields are restricted to be parallel to certain directions are said to be linearly polarized waves. As sunlight is a mixture of the diversity of waves the sunlight beam is not polarized wave. There exist crystals and organic films named polarizers that can transmit through them only the waves with specific direction of electric field called the polarizing direction. Waves of the beam with other directions of the field vectors pass through such materials only partly depending on the relative direction of the electric field vector of the wave and the polarizing direction of the material. If the angle between the polarizing direction of the polarizer and the electric field vector of the wave is $\theta$, and the intensity of the incident linearly polarized beam $I_0$, we can calculate the intensity of the exit beam after passing through the polarizer according to the Malus's law:

$$I = I_0 \cos^2(\theta)$$

The sunlight is unpolarized. Its intensity is reduced by the factor of one half after passing a single polarizer, as the average value of $\cos^2(\theta)$ is ½.

We also must remember that the polarizers usually are not ideal, and can absorb the light as all other transparent materials.

In our problem we deal with two polarizers and the beam of sunlight. The transmitted intensity after the first polarizer reaches $\eta_1 = 30\%$ of the incident sunlight beam intensity. In some arrangement of two identical polarizers, the transmitted intensity will decrease to $\eta_2 = 13.5\%$ of the incident sunlight beam.

Calculate the angle between the polarizing directions of these two polarizers in the described experiment.

5. **Not only music.**

Explain in details the optical phenomena that can be observed with the help of ordinary compact disk. Describe as many results of observation as you can.