EXPERIMENTAL COMPETITION

16 January, 2013

## Please read the instructions first:

1. The Experimental competition consists of one problem. This part of the competition lasts 3 hours.

2. Please only use the pen that is provided to you.

3. You can use your own non-programmable calculator for numerical calculations. If you don't have one, please ask for it from Olympiad organizers.

4. You are provided with *Writing sheet and additional papers*. You can use the additional paper for drafts of your solutions but these papers will not be checked. Your final solutions which will be evaluated should be on the *Writing sheets*. Please use as little text as possible. You should mostly use equations, numbers, figures and plots.

5. Use only the front side of *Writing sheets*. Write only inside the bordered area.

6. Fill the boxes at the top of each sheet of paper with your country (*Country*)**,** your student code (*Student Code*), the question number (*Question Number*), the progressive number of each sheet (*Page Number*), and the total number of *Writing sheets* (*Total Number of Pages*). If you use some blank *Writing sheets* for notes that you do not wish to be evaluated, put a large X across the entire sheet and do not include it in your numbering.

7. At the end of the exam, arrange all sheets for each problem in the following order:

    - Used *Writing sheets* in order;
    - The sheets you do not wish to be evaluated
    - Unused sheets and the printed question.

    Place the papers inside the envelope and leave everything on your desk. You are not allowed to take any paper or equipment out of the room

Advertising tricks [15 points]

Equipment: Laser, tripod with the clip, collecting lens on a stand, cardboard screen, graph paper, two guide rulers, measuring ruler, plate with three optical elements:
1. Fresnel mirror (square piece of foil with applied rings);
2. Glossy reflective stripe.
3. Plastic refractive element (orange piece of material covering the hole)
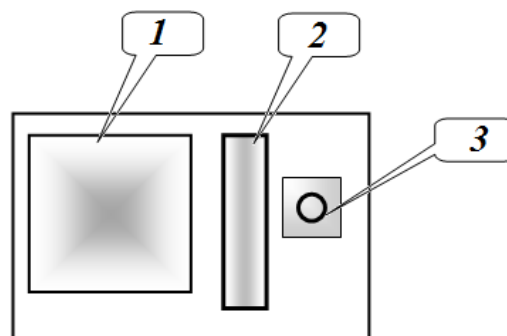
Turn on the laser only when you take measurements!
The wavelength of the laser beam is $\lambda = 680 nm$.

Part 1.Lens

In this part of the problem the laser beam deflection angle from the optical axis should be considered small.

Place the lens on the stand between the guide rulers such that it could be moved in parallel to itself. Fix the laser in the tripod clip. Attach the cardboard screen to the laser. Direct the laser beam at the lens center such that the reflected beam is clearly visible on the screen. Ensure that the reflection is approximately backward. When the lens is displaced along the guide rulers the reflected spot moves across the screen. Note that the spot gets diffuse, that is why take measurements of the spot center.
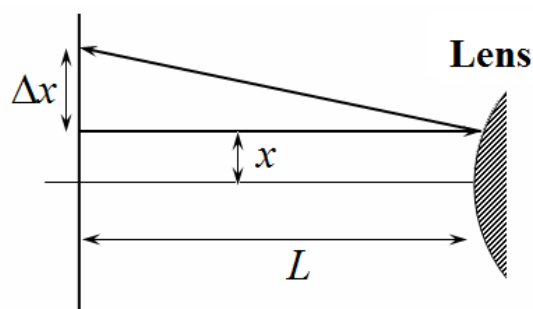
1.1 For both surfaces of the lens, measure the dependence of the displacement Δx of the reflected laser beam on the displacement x of the lens. Plot graphs of the corresponding dependences.
1.2 Using the data obtained, determine the radii R_1 and R_2 of the two surfaces of the lens.
1.3 Place the screen at a certain distance L behind the lens. Measure the dependence of the displacement Δx of the refracted laser beam on the lens displacement x. Plot the corresponding graph.
1.4. Using the experimental data obtained, determine the focal length of the lens.
1.5 Calculate the refractive index n of the lens material. Evaluate the experimental error of the refractive index.
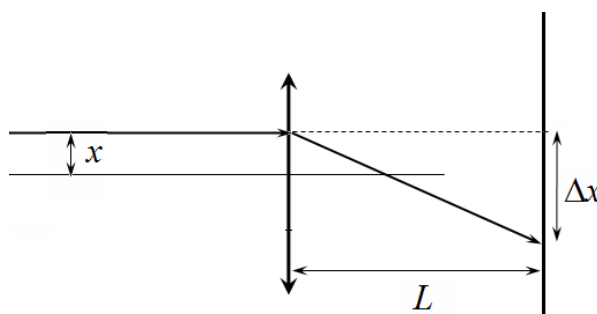
Hint: You can use the following formula for the focal length F of the lens

$$\frac{1}{F} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right).$$

In the following parts of the problem estimation of errors is not required!

Part 2. Fresnel mirror

Using a piece of plasticine attach the plate with the optical elements to the lens, i.e. use the lens as a stand only.
Place the lens with the plate between the guide rulers such that the laser beam directly hits the Fresnel mirror. Place the laser with the screen at a distance of 15-20 cm from the mirror. Carefully adjust your installation such that the laser beam moves along the mirror diameter when the mirror itself is displaced. You should see the diffuse reflected spot which should move almost horizontally at the level of the incoming laser beam when the mirror is slightly displaced.
The Fresnel mirror is a set of concentric rings whose radii vary with the number k, counted from the center, according to the law

$$r_k = r_0 k^\gamma \tag{1}$$

In this part of the problem deflection angles cannot be considered small.

2.1 Measure the displacement of the center of the reflected spot Δx_1 as a function of the mirror displacement x. Plot the graph of the sine of the reflection angle as a function of the mirror displacement.
2.2 Estimate γ in formula (1).

Part 3. Glossy reflective stripe

Direct the laser beam onto the glossy reflective stripe 2. You can observe a few reflected beam on the screen.

3.1 Make a guess on the structure of the glossy reflective stripe that could explain the observed pattern of the reflected beams. Calculate the numerical values of the parameters of this structure.

Part 4. Plastic refractive element

Direct the laser beam on the hole with the plastic orange element. This element has a three-dimensional structure. Place the screen behind this element, you should see a number of bright spots in the transmitted light.

4.1 Make a guess on the structure of this element that could explain the observed pattern of the reflected beams.
4.2 Estimate the refractive index of the material from which this optical element is made of.