2004-2005 Physics Olympiad Preparation Program

– University of Toronto –

We continue the competition for the best problems created by our POPTOR contestants. Name your self-made problem as "My Problem", and mail this problem and its solution on a separate sheet of paper as an attachment to the solutions of POPTOR problems. You may send us any number of problems, but only self-made and unique will be considered. Authors of the best problems will be awarded regardless of their POPTOR results

Problem Set 4: Optics

Due February 7, 2005

Problem 1.

A beam of light from a point source S passes the motionless glass prism along the side with the length $\boldsymbol{l}$ and hit the wall.

1) Will the beam reach the wall faster or slower if the prism moves to the wall with speed $\boldsymbol{v} \ll \boldsymbol{c}$, where $\boldsymbol{c}$ is the speed of light in free space.

2) What is the difference in times of propagation of a beam in the cases of motionless and moving prism if index of refraction of the glass is $\boldsymbol{n}$?

3) ***Bonus question (3 additional points)***. What is the solution when speed $\boldsymbol{v}$ is of the same order of magnitude as $\boldsymbol{c}$ (relativistic problem)?

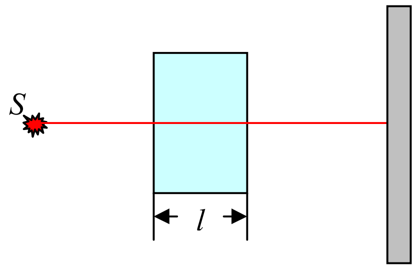

Fig.1

Problem 2.

A cylindrical container with mercury uniformly rotates around the vertical axis with angular speed ω. Astronomers use the surface of mercury in this experiment as a mirror.

1) What is the shape of the mercury surface?

2) At what position should a photo film be put to get a clear picture of a distant star?

Problem 3.

A plane wave with the wavelength $\lambda = 0.5$ mm is incident perpendicularly on a barrier in which there are four parallel slits of the width $d = 0.2$ mm each. The distance between slits is $D = 5$ mm.

1) Find the direction on the first-order minimum.

2) Suppose one of the internal slits was closed. Calculate the new direction on the first-order minimum.

Problem 4.

A light wave, as any other electromagnetic wave, is called the linearly or plane-polarized, if vector $\vec{E}$ and the direction of propagation of the wave always lie in the same plane. This plane is called the *plane of polarization*. A material is said to be optically active if it rotates the plane of polarization of the light wave transmitted through the material. One of such substances is a water solution of an ordinary sugar. Angle of rotation of the plane of polarization φ is directly proportional to the length l of the light path in such solution:

$$\varphi = \alpha l$$

α is a rotation constant for this substance. If a beam of plane-polarized light after passing through the optically active substance reflects back and passes through the same substance in the opposite direction, its plane of polarization returns to the initial state.

There is another source of rotation of the plane of polarization – magnetic field in some substances. It is called a Faraday rotation. The angle of rotation ϕ in the magnetic field B is also proportional to the length of the path l of a light beam in a magnetic field:

$$\phi = \beta l B$$

β is a constant. The direction of rotation depends on the direction of magnetic field and does not depend on the direction of propagation of the light wave.

A beam of plane-polarized light passes through the right-rotating substance that exists in the magnetic field ***B***, as it is shown in Fig.2. The length of the container in the direction of propagation is l. Constants α and β are known.

Find the total angle of rotation of the plane of polarization for the exit beam.

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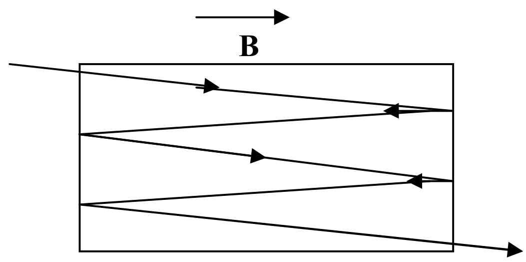

Fig.2

Experiment

Determine index of refraction of water using a thin stick, glass with water and a ruler. Describe your experiment in detail and submit the description with a drawing. Perform at least 5 measurements and calculate the mean and statistical (random) error of the series of experiments. Compare the result of your experiment with the tabulated value (n = 1.34), and calculate the absolute and percent difference. Make a conclusion on the precision of your method.