

2005-2006 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 the 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 and Waves

Due February 6, 2006

Problem 1

A bat, moving at 5.00 m/s, is chasing a flying insect. If the bat emits a 40.0 kHz chirp and receives back an echo at 40.4 kHz, at what speed is the insect moving toward or away from the bat? Take the speed of sound in air to be $v = 340$ m/s.

Problem 2

A surface of a glass plate is covered with a thin layer of water. Light with the wavelength $\lambda = 0.680 \mu\text{m}$ strikes the surface at the angle 30.0° with respect to the normal to the surface. Due to the evaporating of the water layer, the intensity of the reflected light changes periodically. The time interval between the appearances of the maximum of intensity is equal to 15.0 min. Indices of refraction of glass and water are respectively 1.50 and 1.34. Find the rate of decrease of the water layer thickness.

Problem 3

The diffraction grating has 200 grooves per millimeter. Non-coherent light beam consists of waves with the wavelengths in the range from $\lambda - \Delta\lambda$ to $\lambda + \Delta\lambda$ and average wavelength $\lambda = 550$ nm. The light strikes the diffraction grating along the normal to the surface. Find the maximum value of $\Delta\lambda$, for which the adjacent spectra obtained with the diffraction grating do no overlap.

Problem 4

While an artificial diffraction grating is used to study a spectrum of a light beam, electromagnetic waves with wavelengths much less than the wavelength of the visible light are used to study the natural diffraction grid, namely a crystalline structure. Electromagnetic waves in this range are called the x-rays.

Fig. 4.1 shows a two dimensional description of the reflection of an x-ray beam from two parallel crystalline planes separated by a distance d . The beam reflected from the lower plane travels farther than the beam reflected from the upper plane. The effective path difference is $2d\sin\theta$. The condition for constructive interference is given by Bragg's law:

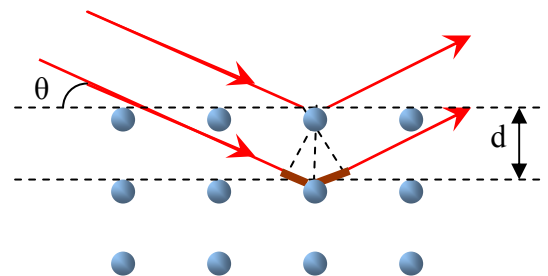


Fig.4.1

$$2d\sin\theta = m\lambda, m = 1, 2, 3, \dots$$

If the wavelength and diffraction angle are measured, the Bragg equation can be used to calculate the spacing between atomic planes.

In our problem, the crystalline of NaCl with density $D = 2.16 \text{ g/cm}^3$ is exposed to x-rays with the glancing angle $\theta = 60.0^\circ$. The reflected rays form the second order maximum.

- (a) Find the wavelength of x-rays used in the experiment.
- (b) Explain why the visible light cannot be used to obtain the diffraction pattern on crystals.

Problem 5 (experimental)

Using an available diverging lens (e.g. of the glasses), measure the focal distance of the lens.

Propose as many methods of this measurement as you can.

Explain in detail every method, submit it with the list of equipment, and sketch an experimental setup.

It is important to submit your solution with a guide in such a way that the members of POPTOR team will be able to follow your instructions and perform similar measurements to find the focal distance of their glasses with diverging lenses.

No error analysis is needed. However, the comparison of your result with the known value (for glasses) or the comparison of the results of different methods will be rewarded.