

2002-2003 Physics Olympiad Preparation Program
- University of Toronto -
Problem Set 4: Waves and Optics
Due: 10 February 2003

1. A cube of ice C , the sides of which are length $L = 1$ metre, is placed in water. When the water and C come to rest, 0.5 metre of C is above the surface of the water. The cube is raised vertically out of the water by a small amount and then released. Prove that C exhibits simple harmonic oscillation. Ignore damping (friction). What is the frequency of the water waves produced by the oscillating ice cube? The density of water (ice) is $\rho_{water} = 1000 \text{ kg/m}^3$ ($\rho_{ice} = 900 \text{ kg/m}^3$).

2. A point source of sound waves S moves with constant speed v . Its power output is P . What is the wave intensity measured at a distance r in front of S ? The speed of sound is v_s .

3. A light beam travels from air through a medium of thickness L and index of refraction $n > 1.2$ (Figure 1). Upon entering the medium, the beam makes an angle θ with the surface normal. Prove that the beam exits the medium shifted by a distance x with respect to the direction of entry. Express the index of refraction of the medium in terms of θ , L , and x .

4. Two point sources are a distance d apart. They emit spherical waves of wavelength λ . The intensity of the waves is detected along the z -axis as indicated in Figure 2. Where are the points of maximum intensity along the z -axis? Is there an infinite number of maxima on the z -axis? Explain your answer. What is the intensity at the minimum on the z -axis closest to the sources?

5. Place an extended object O at the bottom of a container filled with water (Figure 3). View O from various angles and distances. Try looking at O with your head oriented at different angles. Is the horizontal distance to O that you see altered by the water? Explain your observations.

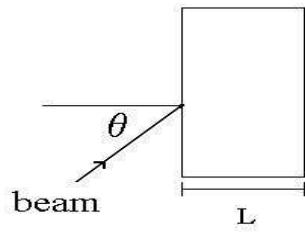


Figure 1

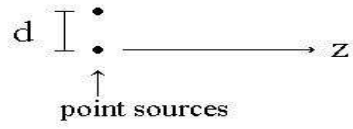


Figure 2

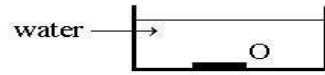


Figure 3