

# 1995-1996 Physics Olympiad Preparation Program

– University of Toronto –

## *Problem Set 4: Wave and Optics*

*Due January 22<sup>th</sup>, 1996*

1. As a physics-illiterate rock concert organizer on Lilliput island (remember Gulliver's Travels), Donald Armen is still puzzled by the complaints from the rock fans. In fact, one of the two speakers was destroyed. He just cannot believe it. He bought a new speaker to increase the loudness of this mono sound system to the one he had. He placed them 8.00 m apart. The closest audience member, Christie, was 10.0 m away from each speaker, respectively (or 9.17 m from the midst of the both). Can you help him understand what was going on? Assume the average frequency is 690 Hz (being tiny, these Lilliputs have high pitch). The speed of sound is 344 m/s.
  - (a) Could Christie hear the concert?
  - (b) Albion, standing on Christie's left, was among the ones who got angry and destroyed the speaker. He just barely listen to the concert. Where did he stand?
  - (c) This fiction is far from reality. Explain!
2. A group of police cars moving at 80 km/hr are chasing O'Samson's white Bronco, which is travelling at the same speed. They are afraid that this former famous hockey player will commit suicide. It seems that 3000-Hz sirens from the police car do not bother him much.
  - (a) What is the wavelength of the sirens in the air between O'Samson and his chasers?
  - (b) What frequency does he actually hear?

The speed of sound is 344 m/s.

3. Learning from Donald Armen's story (Problem 1), you decide to study more about loudspeakers. You place two small loudspeakers facing each other at the two ends of a 5.0m-bench. The first loudspeaker emits a sound of pressure amplitude twice as much as the second one. Both sounds are at 1334 Hz and are in phase at the speakers.
  - (a) At what point on the line joining the two speakers is the intensity a minimum?
  - (b) What is the intensity compared to one from the second speaker alone?
  - (c) At what other points on the line joining the speakers will destructive interference occur?
  - (d) At what point on the line joining the speakers is the intensity a maximum?
  - (e) Express the maximum intensity terms of the intensity from the second speaker!
4. Your professor told you that diffraction gratings are better than prisms for atomic and molecular spectroscopy. You don't believe it; you are sceptical .... So you perform experiments using both and you finally agree with him. Why is your professor right? To support your arguments compare your calculations for both prism and diffraction grating for a source light which emits 434 nm (blue), 486 (green blue), 589 nm (yellow) and 656 nm (red). Take the indices of refraction of heavy flint prisms  $n = 1.675, 1.664, 1.650,$  and  $1.644$ , which correspond to the wavelengths above, respectively. The angle of the prism is  $A = 60^\circ$  and the diffraction grating has 8000 lines per centimeter.
5. Kids love to play with soap bubbles and are always fascinated by them. Ok, ... you are not kids anymore but you need to guess what colour a bubble of 400 nm thickness appears to be. Need some hints? Alright.
  - (a) What colours do not appear in the reflected light?

- (b) For what colours does constructive interference occur?
- (c) So the colour of the soap bubble is predominantly ....

The index of refraction of the soap film is 1.36.

6. Ok, let us have a break now with a few small questions.

- (a) Most large astronomical telescopes in use today are reflectors rather than refractors. Why is this so?
- (b) You are able to find a very sharp focal length of a crystal ball. Right or wrong? Explain.