Physics 225

Homework Assignment 4

Due 5 February 2008

1 Directional microphones

A directional microphone works as follows. It contains several small microphones arrayed in a line:

so the line has a total length d. Each microphone records the pressure at that location. The pressure, as a function of time, is digitized, and the results for the different microphones are added, but with a different time delay introduced for each microphone (so for instance the pressure as seen in the back microphone can be added to the pressure the front microphone received a time Δt earlier). The microphones are evenly spaced.

How should the delays be chosen, so that a sound arriving from in front of the line of microphones will get added constructively by this process, while sounds coming from the sides will get (partly) canceled out?

Most of the "information" in speech is received in frequencies between 500 and 3000 Hertz. How long does a directional microphone need to be for sound coming from the side to be effectively canceled over this whole frequency range?

[Hint: READ the section in the notes about directional microphones!]

2 sound diffraction gratings

Some of the cement walls in the physics building have regular vertical grooves. (Look at the wall right across from the classroom, for instance.) There are also a few walls in the entry area of the Leacock building with similar vertical grooving.

Measure the spacing between vertical grooves in one or the other building. Write your answer in centimeters or in meters. What frequencies of sound can display a "diffraction peak" in which a large amount of sound deflects at an angle very different than the usual "Angle of incidence = Angle of repose"? Below what frequency do these walls act just as if they were flat "sound mirror" surfaces?

3 Sound directionality from wind instruments

A trumpet's sound is produced from the opening of the bell, which is a disk (filled circle) about 11 cm in diameter. The French Horn's sound also emerges from the bell, but in this case it is 31 cm in diameter.

At what frequency does the sound from a trumpet start to be "beamed" from the opening? (Take as a criterion for the note to be beamed, that the angle of the first "node" or direction where the sound power has a minimum should be forward, meaning $\theta < 90°$.) What is the frequency where the French horn's sound starts to be "beamed"? Compare this to the nominal range (bottom and top note) of each instrument, around 165 Hertz to 1300 Hertz for the trumpet and 68 Hertz to 1000 Hertz for the French horn.

The sound a trumpet or horn produces is actually not a sine wave; much of the sound power emerges as "harmonics" (sine waves with 2,3,4,. . . times the frequency of the note being played). Will the relative loudness of the "fundamental" played note and these "harmonics" which accompany it depend on the viewing angle (in front of versus to the side or behind the instrument)? Do you think it matters that the French horn bell is usually pointed downward, or that the musician often stuffs their hand into the bell?

The opening at the end of the flute is only about 2 centimeters in diameter. The sound either comes out of this end, or out of one or more finger holes which are even smaller. The highest note the flute plays is around 2000 Hertz and the harmonics are very weak (ignore them). Do you expect the sound of the flute to come out equally in all directions or to be beamed?