UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS, DECEMBER, 2000

Fourth Year - Programs 5, 7

ECE446F - ELECTROACOUSTICS

Examiner: H. Kunov

Examination Type: A
(Non-programmable calculator allowed)

There are 9 problems with a total of 17 questions. The 17 questions carry equal weight.
Some useful information is appended on Page 4.

1. The wave equation for a spherical acoustic signal can be written as $\frac{\partial^2(pr)}{\partial r^2} = \frac{1}{c^2}\frac{\partial^2(pr)}{\partial t^2}$.

What is the expression for a 500 Hz sinusoidal spherical wave satisfying this expression when we know that at the sound pressure level at r = 1 m is equal to 50 dB SPL, and the sound pressure has its maximum positive peak at t = 0 at that point?

2. An empty beverage bottle (for instance a wine bottle) is a Helmholtz resonator. Determine the resonant frequency of a 750 ml bottle, estimating those parameters that you need.

3. A given sound source produces white noise in the band 100 Hz – 10 kHz. The sound level is 75 dB SPL.

a. What would we measure if all noise between 1 kHz and 10 kHz was removed?

b. Same question, given that the sound source produces pink noise.

4. A pure tone is swept from 30 Hz to 6 kHz with the level adjusted such that an A-weighted sound level meter reads 25 dB A. Determine the corresponding loudness in sones, using frequency as the abscissa.

5. Someone is listening to white noise at 90 dB SPL. The level of the signal is now reduced by 60 dB (the same amount at all frequencies). Determine the frequency response of a filter that will make the lower-level noise sound like the original one.

6. A certain worker is exposed to noise from machines A, B, and C. The table below shows the noise levels at his work station from each of the machines operating by itself, and times during the day that the machines operate.

Machine↓ Time→	8 – 10 am	10 – 12 noon	Noon – 1 pm	1 – 3 pm	3 – 5 pm
A	80 dBA	80 dBA	-	-	80 dBA
B	-	90 dBA	-	90 dBA	90 dBA
C	85 dBA	-	85 dBA	85 dBA	85 dBA

a. Determine the 9-hour Leq to which the worker is exposed.

b. Determine how when in the afternoon the worker should leave for his 9-hour Leq to be reduced by 3 dB. Assume that he spends the extra time in an environment with a noise level of 65 dBA.

7. Six identical loudspeakers are mounted on the six sides of an air-tight plywood cube with inner dimensions 20 cm on the side. Each of the speakers has the following properties: Effective diameter 15 cm, $Bl = 2.4$ Tm, R = 8 ohm, mass of voice coil and cone 32 gram. The speakers are coneected in parallel such that they all move in and out at the same time, for a given electrical input.

a. Draw a formal electro-acousto-mechanical diagram of the system, disregarding the loading by the air outside the box.

b. If a 2 volt d.c source is connected to the speakers, what steady-state air pressure would we expect in the box?

c. Determine the electrical impedance at 350 Hz (between the terminals of the parallel-coupled speakers).

d. One of the speakers is now disconnected from the other five (which are still connected in parallel). A 10 volt, 350 Hz sinusoidal source is connected to the single speaker. Determine the voltage that appears across the terminals of the five speakers in parallel.

8. A room in the shape of a simple box has dimensions 15 m x 10 m x 5 m (length x width x height). The walls are covered with a material with an absorption coefficient of 0.15, except for an area of 2 m x 3 m where there is a window (absorption coefficient 0.08). The ceiling has an absorption coefficient of 0.23, and the floor 0.12. A single person corresponds to a Sabine area of 0.54 m^2.

   a. Determine the reverberation time of the empty room.
   b. What is the reverberaion time if half the window area is opened to the outside?
   c. With the window closed, how many people would it take in the room to reduce the reverberation time by 0.35 seconds?

9. A certain wall is covered with natural field stones set in concrete. From an acoustic point of view, the surface has a random deviation from the original flat wall. The peaks and valleys are mostly between + and – 10 cm, and the spatial frequency of the irregularities is around 10 peaks per metre.

   a. Discuss the use of ray acoustics for this wall, with particular reference to frequency of the signal.
   b. A sound source, consisting of a 1/3-octave noise band centered on 10 kHz sits 2 metres from the wall, which for the purposes of this problem is infinitely large in both dimensions, and the only object nearby. The direct sound from the source to a sound level meter 1.5 metres away, but also 2 metres from the wall, measures 66.5 dB SPL. Determine the sound pressure level of the direct plus the reflected signals.

1m from wall