UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS, DECEMBER, 1999

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 15 questions. The 15 questions carry equal weight.
Some useful information is appended on Page 4.

1. Dry air consists of nitrogen, oxygen, carbon dioxide, and argon as shown to the right. Determine the velocity of sound in inspired and expired air (ignoring water vapour), assuming that expired air contains 4% CO_2, and correspondingly less O_2.

Constituent	Content (by vol)	Density
N_2	78.08%	1.251 kg/m^3
O_2	20.95%	1.429 kg/m^3
CO_2	0.03%	1.977 kg/m^3
Ar	0.93%	1.783 kg/m^3

2. You are asked to design an enclosure that can be used to test the effect of infrasound on people. The enclosure is sealed airtight, and has the dimensions 2 m x 3 m x 2.5 m. We wish to generate sound pressures in the enclosure of up to 80 dB(SPL) at 10 Hz. The infrasound is generated by one or more loudspeakers fitted and sealed into holes in the walls.

a. How many loudspeakers are required, given that each has a diameter of 35 cm, and a maximum displacement of ±0.3 cm?

b. At what frequency will we have the first room resonance?

c. Although the enclosure is designed to be airtight, there is nevertheless a certain leakage because of imperfect sealing, for instance around the access door. Determine the corresponding acoustic resistance for a leakage that gives rise to a 1 dB error at 10 Hz.

3. The noise from the fan of a piece of office equipment was measured with "linear" weighting in octave bands at a particular location, as shown in the table below.

Frequency (Hz)	31.3	63	125	250	500	1k	2k	4k	8k	16k
Level (dB(SPL))	66.5	68.3	50.1	45.8	47.6	42.7	44.0	41.8	32.3	29.5

a. What level would you measure with the sound level meter set to "linear" and without any filtering?

b. What level would you measure with A-weighting, still without any filter?

4. The sound level from a single source is 56.3 dB(A) at a distance of 7.5 metres from the source. Assuming free field conditions, what level would you expect at a distance of 4.5 metres from the source?

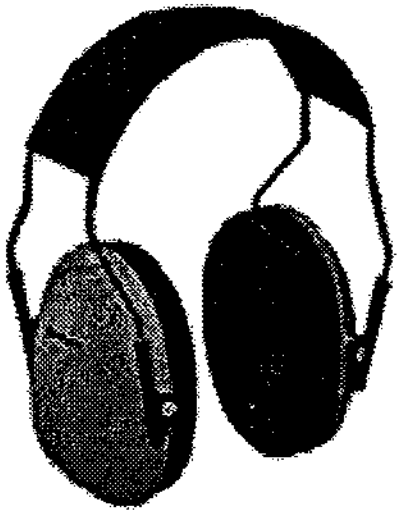
5. A worker is exposed to an Leq of 88 dB(A) during a normal work day of 8 hours. It is proposed that she changes to a different kind of work, where she will be exposed to 95 dB(A) for n hours per day, and to 70 dB(A) for the rest of the 8-hour day. What is the value of n, so she receives the same exposure over the working day in the new work situation as she did in the old one?

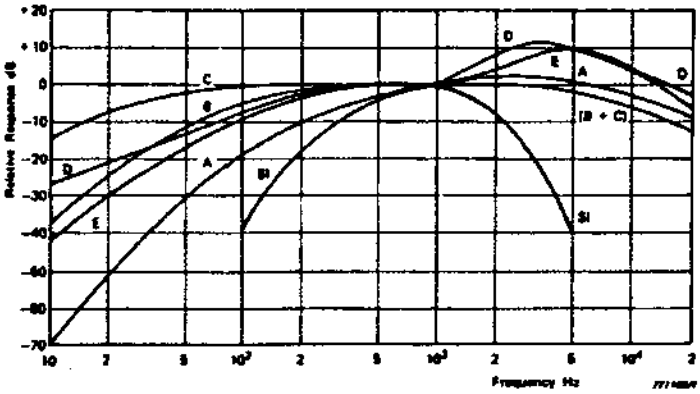
6. A certain lecture room with 230 seats has a reverberation time of 1.85 seconds when it is empty. The room is box shaped with dimensions 8.5m x 15m x 5m. Assuming that each person in the audience corresponds to a Sabine area of 0.55 m^2, what are the reverberation times for the room when half full and completely full?

7. An 80 Hz pure-tone signal increases in level by 1 dB per second, staring at 20 dB(SPL) at t = 0, and ending when the level is 100 db(SPL). Plot the loudness level in sones as a function of time.

8. A loudspeaker is mounted in the wall of an otherwise closed box. The effective diametar of the speaker is 12.5 cm, Bl = 7.3 Tm,and the compliance of the mechanical speaker suspension is $1.25 \cdot 10^{-3}$ m/N. The mass of the moving parts of the speaker is 55 gram, and the electrical resistance of the coil is 6 Ω. The volume of air in the box produces a compliance equal to that of the mechanical suspension of the speaker.
   a. Determine the volume of the box.
   b. What is the electrical driving-point impedance of the speaker at 800 Hz?

9. A circumaural (so-called "muff" type) hearing protector has a rigid cup and a soft cushion between the cup and the head. The cup has a mass of 150 gram. The cushion, together with the skin and soft tissue in the skull, has a stiffness of $75 \cdot 10^3$ N/m, and a damping D that is unknown. The volume of air under the cup is $2.1 \cdot 10^{-4}$ m^2. There is leakage, due to hair, the frame of eye glasses, and lack of perfect fit, corresponding to a 2 cm long channel with a cross-sectional area of 3 mm^2.
   a. Draw a formal acoustic diagram of the system, including numerical values and units..
   b. Disregarding the damping D, determine the frequency response of the muff, i.e., the the pressure under the cup divided by the pressure outside, over the auditory range.
   c. Now, consider the damping D from the cushion (and soft tissues). Discuss the effect of D on the frequency response, and suggest a practical value to aim for in the light of the frequency response above, and the physical significance of D over a range from very small to very large values.





The internationally standardized weighting curves for sound level meters and recently suggested E and SI weighting

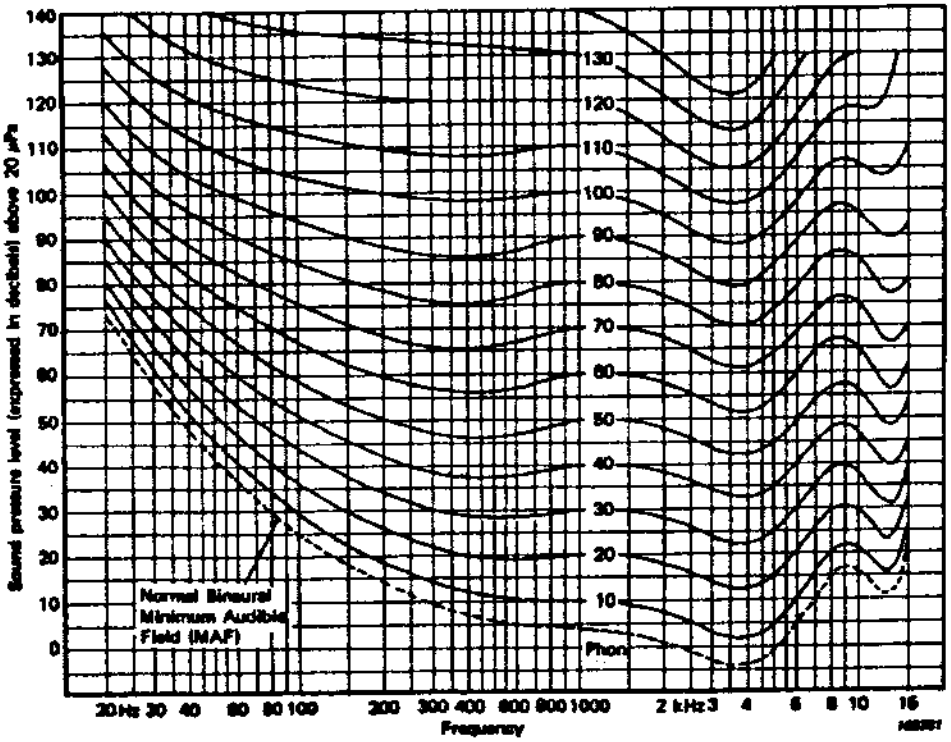
1 atmosphere (normal)= 1.0133×10^5 Pa

Ratio of specific heats for an ideal gas = $c_p/c_v = 1.4$

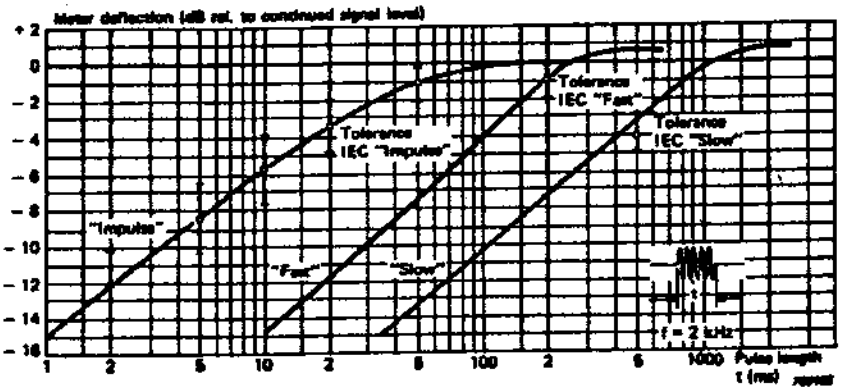
Reference acoustic pressure = 20 μPa in air (1 μPa in other media)

Density of air (normal) = 1.18 kg/m^3

Speed of sound in air: 344 m/s.
In fresh water: 1480 m/s



Normal Equal Loudness Contours for pure tones



Response of meter to tone bursts of varying duration