UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS, DECEMBER, 1998

Fourth Year - Programs 5, 7

ECE446F - ELECTROACOUSTICS

Examiner: H. Kunov

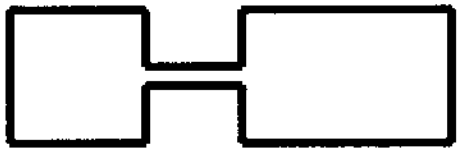
Examination Type: A
(Non-programmable calculator allowed)

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

   Given, that the sound pressure level of a spherical, divergent 10 kHz pure tone-wave at r = 1 m is 40 dB, write the expression for pressure as a function of time and distance (r) from the centre, and verify that it satisfies the wave equation.

2. A hard-walled tube connects two hard-walled cavities. The cavities have volumes of 0.68 and 1.44 litres, and the connecting tube has an inner diameter of 1.6 cm and a length of 8.8 cm.



   a. Give a formal acoustical diagram as well as an analog electrical circuit of the acoustical system.

   b. Determine the resonant frequency of the system.

   c. A second, identical tube is now installed between the two cavities, in parallel with the original one shown above. What is the new resonant frequency?

3. The sound pressure level from a 550 Hz pure tone, immediately in front of a loudspeaker cone is 83.5 dB(SPL). The cone has an effective diameter of 23.6 cm, and the product of the length of the voice coil wire (l) and the magnetic field (B) is $B \cdot l = 0.76$ Tm. The mass of the voice coil plus speaker cone is 28 gram.

   a. Determine the voltage on the open-circuited terminals of the loudspeaker due the sound field.

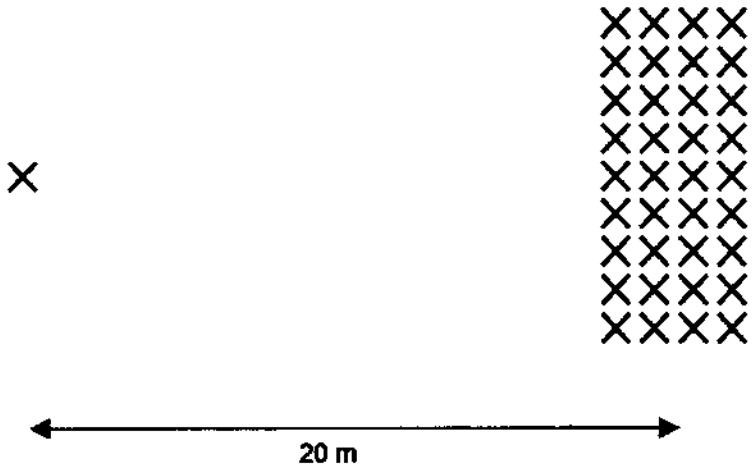
   b. What is the amplitude of the excursions of the voice coil?

4. White noise within the band 20 Hz – 20 kHz is measured with a sound level meter.

   a. Estimate the difference in the readings between "Linear" and "A-weighted" measurements of the noise.

   b. What would the answer be if we were dealing with pink noise?

5.



The single cross in the figure above represents a sound source 5 feet above ground (for instance, a lecturer), and the 36 crosses on the right represent listeners. The setting is an open field with horizontal ground, and you have five full sheets of plywood (4 feet x 8 feet) that can conveniently be placed in any vertical plane, so long as one side rests on the ground. Sketch an arrangement of the plywood sheets (including which side is on the ground) that will improve the sound level for the listeners. Justify your placement, referring to ray acoustics and the Precedence Effect.

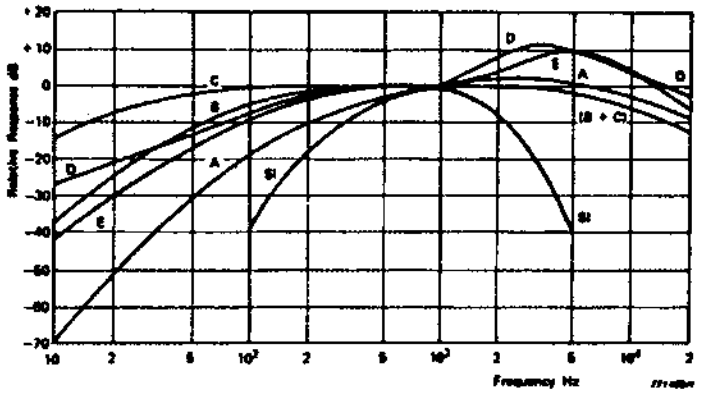
6. A piece of classical music was recorded for reproduction at a level of about 70 phon. Sketch the frequency response of a filter that would equalize the sound if the volume is reduced to 30 dB at all frequencies.

7. We wish to determine the effect of loud rock concert music on the overall noise exposure for two persons (A and B) with different work. Both A and B work 9 am to 5 pm, five days a week. A works in an office with an 8-hour L_{eq} of 60 dB(A), and B in a factory with an L_{eq} of 85 dB(A). For the rest of the day, and on weekends both A and B experience L_{eq}'s of 65 dB(A), except for Friday and Saturday nights when they both go to rock concerts. Each concert lasts 3 hours and the L_{eq} is 105 dB(A).
   a. Determine the weekly (168-hour) L_{eq} for both A and B.
   b. What difference would it make in their individual 168-hour L_{eq} if they went to a classical concert (L_{eq} = 75 dB(A)) instead of the rock concert?
   c. B decides to use hearing protectors that reduce the sound level in the ear by 20 dB. Is it better to use them during the 6 hours of rock music or during the 40 hours of work? (Determine the corresponding L_{eq}'s).

8. The auditory system exhibits "temporal integration" of signals shorter than $1/5$ second.

   What are the most appropriate time weighting ("slow", "fast" or "impulse") and frequency weighting ("A", or "C") for a sound level meter to reflect the loudness of a fluctuating noise that is (1) barely audible, and (2) near the pain threshold?

9. Five identical industrial machines operate simultaneously, and together produce a noise level of 91.6 dB, measured at a certain point in the room. All the machines are close to a concrete wall with an absorption coefficient of 0.35. We wish to reduce the noise level by adding a highly absorbent material to the wall. What is the best noise level we can hope for, given that the new material is perfectly absorbent, and that reflections from the other surfaces in the room do not contribute to the noise?



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

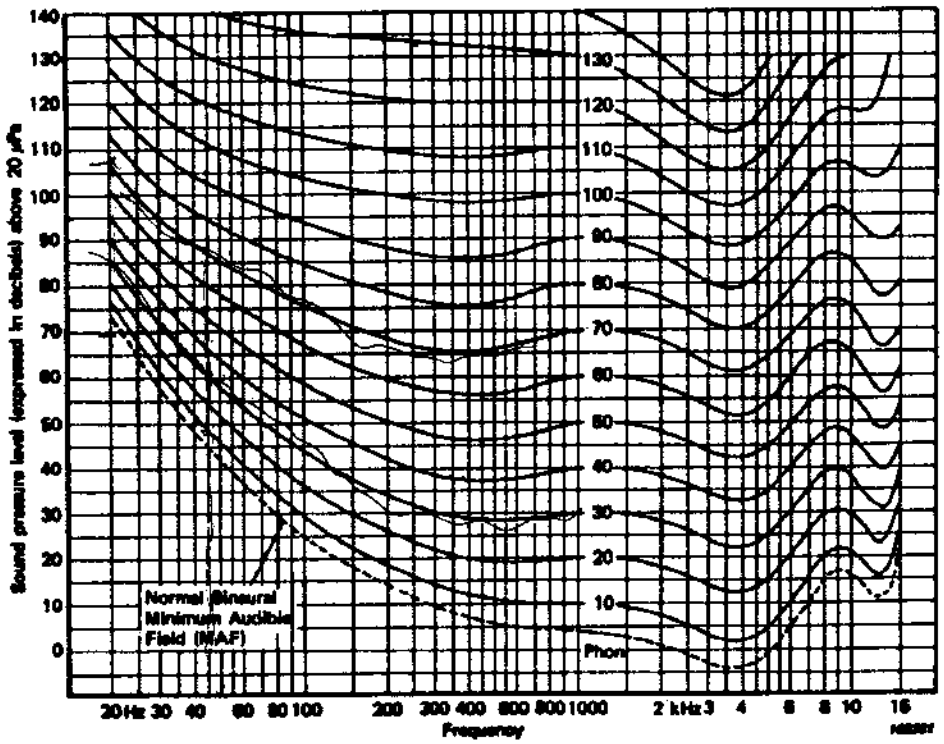
1 atmosphere (normal)= 1.0133×10^5 Pa

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

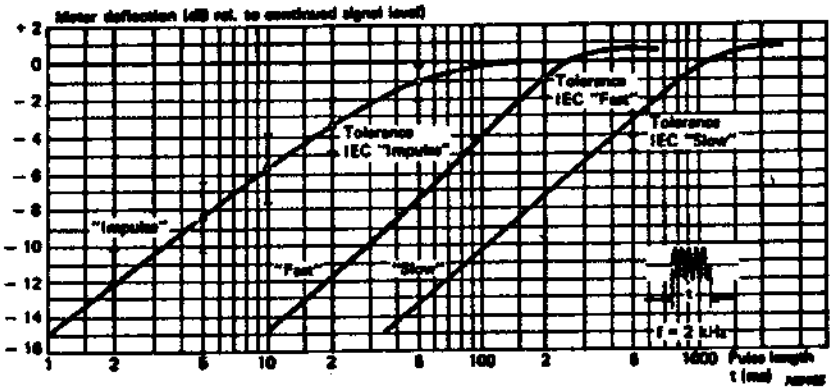
Reference acoustic pressure = 20 μPa in air (1 μPa in other media)

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