**ECE 537** **HW #1** **Fall 2007**

**Univ. of Illinois** **Due: Friday Aug. 31, 2007** **Prof. Allen**

**Topics of this homework:** Basic Acoustics and units, dB, Intensity calculations, the Helmholtz resonator

1. The speed of sound:
   (a) What is the formula for the speed of sound?
   (b) Identify the variables.
   (c) What is the meaning of $\eta P_0$?
   (d) Numerically show that $c^2\rho_0 = \eta P_0$. Namely given numerical values for each of the constants, show that the left is equal to the right.
   (e) Does $P_0$ depend on temperature? Explain?
   (f) Does $\rho_0$ depend on temperature or $P_0$? Explain.
2. Basic equations of sound propagation:
   (a) Write out the 2x2 matrix equation that describes the propagation of 1 dimensional sound waves in a tube having area $A$:
   (b) Rewrite these equations as a second order equation in terms of the pressure $P$, and thereby find the formula for the speed of sound in terms of $Z$ and $Y$:
3. Assume that a flash bulb puts out 50 Joules when it is triggered, and it lasts for 20 $\mu$s. How much power is delivered while the flash is present, assuming the illumination is constant during the interval?
4. A person is speaking at an intensity of $I_0$ 66 dB-SPL, as measured with a sound level meter at 1 meter.
   (a) Find the total power in the voice assuming that the level is uniform around the head.
   (b) Find the total power assuming that the intensity varies as
   $$I(\theta,\phi) = I_0 cos(\theta/2) cos(\phi/2) \quad (1)$$
   where $\theta$ is the angle in the horizontal plane and $\phi$ in the vertical plane. where $\theta = 0, \phi = 0$ corresponds to "straight ahead."
5. Bels
   (a) How many millibels [mB] in 1 bel [B]?
   (b) Give the formula for the intensity in mB units.
   (c) Give the formula for the sound pressure level in cB (centibel) units.
6. Demonstrate that $P_{ref} \equiv 20$ $\mu$Pa is the same as $I_{ref} \equiv 10^{-12}$ [W/m$^2$].
7. A bottle has a neck diameter of 1 [cm] and is $l$ =1 cm long. It is connected to the body of the bottle "barrel" which is 5 cm in diameter and $L$ =10 cm long. Treat the barrel as a short piece of transmission line, closed at one end, which looks like a compliance $C = V_{barrel}/\eta P_0$, and the neck which look like a mass $M = \rho_0 l/A_{neck}$. These two impedances are in series, since they both see the same volume velocity (flow).

(a) Find the resonant frequency of the bottle. Hint: set the impedance to zero and solve for the resonant frequency in terms of $M$ and $C$.

(b) write out the formula for the resonant frequency in terms of the dimensions of the bottle.

(c) calculate the resonant frequency in Hz for the dimensions given.

(d) Blow into a blottle and measure the resonant frequency by recording the tone, and taking the FFT of the resulting waveform, and finding the frequency (Extra credit).