**UNIV 213 Science & Engineering of Music & Sound Spring 2020**

**Homework Assignment #1 – due in BRKI 368 at 5:00 pm on Monday, Feb. 10, 2020**

***Instructions, notes, and hints*:**

Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work. If you justify any approximations you make, you will be given full credit for such answers.

***Assignment*:**

**1.** The minimum and maximum temperatures ever recorded on earth are approximately −89 °C and 58 °C, respectively. Find the corresponding speed of sound in air for each case.

**2.** Suppose that a culvert (drain pipe) under a narrow road is 4.0 m long and has a diameter of 60 cm. Find the lowest resonant frequency of the culvert for the case when the air temperature is 21 °C (about 70 °F). Also find the lowest resonant frequency on a day when the air temperature is 0 °C (at the freezing point). Don't forget to account for end correction.

**3.** The extreme range of frequencies of the musical notes played in an orchestra spans roughly 50 Hz to 15 kHz. Find the corresponding range of wavelengths in air at room temperature (21 °C or70 °F).

**4.** To the nearest tenth, find the number of octaves spanned by the most extreme range of human hearing (20–20,000 Hz). Recall that an octave is a 2:1 range of frequencies.

**5.** Suppose you observe a lightning strike during a thunderstorm. You happen to have a stopwatch with you (who wouldn't?) and discover that the thunder associated with the lightning arrives 3.5 seconds later. Assuming that the air temperature is 29 °C and the relative humidity is 90%, determine how far the lightning was from your location.

**6.** The human outer ear canal is roughly 2.5 cm long and 0.7 cm in diameter. Assuming that the canal can be approximated as a cylindrical pipe, find its lowest resonant frequency at room temperature (21 °C). Speculate on how your answer might relate to Figure 5.1 of the textbook (Rossing, et al., 3rd ed.).

**7.** Assuming that the effective area of the eardrum is 0.50 $cm^2$, find the average force exerted on the eardrum due to a change in air pressure of 0.01 Pa as a result of a normal conversation. Note that, in the absence of sound, the pressure is the same on both sides of the eardrum, so there is no net force pushing on one side or the other. Remember to convert all units to the MKS system (meters, kilograms, seconds, and the units derived from them, like the newton and the pascal). Assuming a force multiplying factor of 30 due to the mechanical advantage of the inner ear bones and the small diameter of the round window on the cochlea, find the average force exerted on the round window due to a normal conversation.

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**8.** Suppose that a certain sound pressure wave can be represented mathematically by the expression below. The text in square brackets is the unit of change relative to the average air pressure. The pressure changes occur in a direction aligned along the *x*-axis. Variable *t* is time. Respond to the following prompts:

a. Determine whether the wave is a traveling wave or a standing wave, and briefly explain your answer.
b. Find the wavelength $\lambda$ of the wave in meters.
c. Find the frequency *f* of the wave in hertz.
d. Determine the speed *v* of the wave in meters per second. (Don't just assume 340 m/s. It could be different in this case.)
e. Determine the maximum change in air pressure from the average value over one complete cycle of the wave, and briefly explain your answer.

$$p(x,t) = 0.0013\cos(9.82x - 3142t) \quad \text{[Pa]}$$

*Hint*: The wave progresses through one complete cycle ($2\pi$ radians) in space over one wavelength and one complete cycle in time over one period.