UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Electrical and Computer Engineering,
Department of Speech and Hearing Sciences, and
Department of Linguistics

ECE 598 The Speech Chain

Homework Set 2

Fall 2006

Issued: Monday, August 28, 2006 **Due:** Monday, September 11, 2006

Reading for problem set 2: Lecture Notes August 28, 2006

Problem 2.1

(a) Comment on the relationship between parts (h) and (i) of problem 1.4, in the previous problem set.

(b) D is 5 semitones above A. Find the frequency, in Hertz, of D_4, given that the next lower A tone, A_3, is at $f = 220$Hz.

(c) What is the RMS pressure, in Pascals, of a sound with a level of 60 dB SPL?

(d) What is the RMS pressure, in Pascals, of a sound with a level of 80 dB SPL?

Problem 2.2

Glottal vibration is the result of two kinds of forces: aerodynamic forces, and stiffness and damping of the vocal fold. For now, let us only consider the stiffness of the vocal fold:

$$\frac{d^2x}{dt^2} = -\left(\frac{k}{m}\right)x \tag{1}$$

In acoustic terms, Eq. 1 governs the undriven, undamped, collision-free vocal fold behavior—undriven because we are ignoring aerodynamic forces, undamped because we are ignoring the viscosity of the tissue, and collision-free because we assume that the two vocal folds are far enough apart to avoid collision. Eq. 1 is a good place to start our understanding of vocal fold mechanics, because it isolates the "control knob" that most talkers use, most of the time, to control pitch: the stiffness, k, of the vocal fold. Stiffness of the vocal fold can be increased by stretching it; stiffness can be decreased by shortening the vocal fold.

(a) Demonstrate that, with no driving forces and no damping and no collisions, the vocal folds can vibrate forever. Hint: follow the steps in the lecture notes, in order to show that $x(t) = A\cos(\omega t - \phi)$ is a solution to Eq. 1.

(b) The moving part of the vocal fold is a ribbon of tissue about 1cm long, about 3mm deep, and about 1mm wide. This ribbon of tissue has the density of water (1 gram/cm^3). What is its total mass?

(c) Suppose that a particular talker speaks at 200Hz. According to the model given in Eq. 1, what is the stiffness of her vocal folds? Be sure to tell me what the units are.

(d) Assume that the vocal fold displacement, $x(t)$, has an amplitude of 1mm. Plot (by hand or using any program of your choice) one full period of the vocal fold displacement $x(t)$, of the vocal fold velocity dx/dt, and of the stiffness force $f(t) = -kx(t)$.

(e) Now suppose that the same talker increases her pitch to 300Hz (an increase in pitch of one musical fifth), without changing her vocal fold mass. What is the new value of her vocal fold stiffness?