EEL6586 – Spring 2000
Exam 1 April 5, 2000

NAME: ______________________________

This exam is open-book and calculator. You may use any books or papers that you like. There are four problems on this exam, you have two full class periods. State your assumptions and reasoning for each problem. Justify your steps and clearly indicate your final answers.

1	**/25**
2	**/25**
3	**/25**
4	**/25**
TOTAL	

1. (25 points)

   For this problem you will analyze the vocal tract model depicted in Figure 3.35c (page 92) of the text for a very simplified situation. Assume N=3 identical concatenated tubes of uniform cross sectional area. The total vocal tract length is L=17.5cm and the speed of sound is c=350 m/sec. Assume that the glottis is closed ($r_G = 1$), and the mouth is slightly open with $r_L = 0$ (this value was reduced to partially model some of the neglected losses in the tube). The cross sectional areas of the tubes are: $A_1 = A_2 = 3cm^2$ and $A_3 = 5cm^2$

   (a) (5 points) Compute r_1 and r_2 for this model.

(b) (10 points) Derive the transfer function $H(z)$ from the input $u_G(n)$ to the output $u_L(n)$.

(c) (10 points) Using your answer from (b), determine the effective sampling rate of the system and the frequency (in Hz) of the dominant formant.

2. (25 points) Assume that white noise excitation $w(n)$ is filtered by an *all-pole* vocal-tract model $H(z) = 1/(1 + .25z^{-2})$ to produce a speech signal $s(n)$. $w(n)$ is defined:

$$E\{w(n)w(m)\} = \begin{cases} 1 & m = n \\ 0 & m \neq n \end{cases}$$

In this problem you will use LPC to derive an all-pole approximation to $H(z)$.

(a) (5 points) Derive the difference equation for $s(n)$. Make sure you get this difference equation correct because you will use it in the next two parts.

(b) (5 points) Compute the autocorrelation function $r(0)$ for the speech signal $s(n)$.

(c) (5 points) Compute the autocorrelation function $r(1)$ and $r(2)$ for the speech signal $s(n)$.

(d) (5 points) Compute the first two LPC coefficients ($p = 2$).

(e) (5 points) Derive $\hat{H}(z)$, the all-pole approximation to $H(z)$. Does your answer make sense?

3. (25 points) This problem studies the signal to noise ratio for quantization of speech. For simplicity, assume the following:

   1) The probability distribution function for speech is uniformly distributed between $+X_{MAX}$ and $-X_{MAX}$ (You should know that this is not accurate).
   2) We quantize speech to 2^B levels using B-bits for quantization.
   3) The speech is from a male speaker and sampled at $f_s = 3$KHz.

   Answer the following questions:

   (a) (5 points) Derive an expression for the noise power in terms of B and X_{MAX}.

(b) (10 points) Derive an expression for the signal power in terms of B and X_{MAX}.

(c) (10 points) How many bits are necessary to achieve 60dB SNR for this speech sample?

4. (25 points) Short Answer.

(a) (5 points) A train of impulses is fed through an all-pole model of $H(z) = 1/(1 + .25z^{-2})$. Sketch the time domain waveform for a few periods assuming $f_s = 3KHz$ and pitch frequency is 300 Hz. Label all important parameters.

(b) (5 points) Sketch the magnitude of the Fourier Transform for the all-pole signal created in problem 4(a). Label all important parameters.

(c) (5 points) Compute the complex cepstrum of $H(z) = 1/(1 + .25z^{-2})$.

(d) (5 points) Explain what happens to your speech when you breath helium into your vocal tract and try to speak. (Hint: the speed of sound in Helium is about 1200m/sec).

(e) (5 points) An LPC10-like coder is designed to compress speech sampled at 8KHz. It uses 50ms windows with 50% overlap. For each window, the coder transmits 10 LPC coefficients (5 bits each), pitch period (6 bits), and a gain factor (5 bits). A pitch period of zero is used to signify unvoiced speech. How many bits per second does this coder require?