I. Questions: 8 points

Q1. Speech sound is a product of the source (____________ flow), the filter (____________ tract), and the radiator (____________ opening).

Q2. Sung vowels and their formants differ from spoken vowels in the appearance of a "singer's formant" in the frequency range between ________Hz and ________Hz.

Q3. Speech sounds originate in the ____________ with vibrations of the vocal ________.

Q4. Resonances of the vocal tract, called ____________, are tuned by changing the length and cross-sectional area of the vocal tract.

Q5. The individual units of sound that make up speech are called ____________. They are divided into two groups: ____________ (that are voiced) and ____________ (that are voiced or unvoiced).

Q6. To analyze speech, it is desirable to display sound level as a function of ________ and ________.

Q7. Such a display for analyzing speech is called a ____________.

Q8. The first two or three ____________ are usually sufficient for the recognition of vowel sounds.

II. Problems: 8 points

The voice spectra for two vowels are shown below. In each spectrum, the vertical lines under the envelope curve represent the strengths of the harmonics of the fundamental pitch of 150 Hz.

P1. The formant frequencies for spectrum #1 are: F₁ = ____________ Hz, F₂ = ____________ Hz, and F₃ = ____________ Hz. Using Rossing, Table 15.3 (on web, handed out), the vowel best representing this picture is (____).

P2. The formant frequencies for spectrum #2 are: F₁ = ____________ Hz, F₂ = ____________ Hz, and F₃ = ____________ Hz and the vowel best representing this picture is (____).

(over)
P3. The simplest acoustic model of the vocal tract is a pipe closed at one end (by the glottis) and open at the other end (at the lips). This pipe has resonances \( f_n = n(v/4L) \) for \( n = 1,3,5, \ldots \). For a pipe with a length \( L = 17 \text{ cm} \), the first three allowed resonances are: \( f_1 = \underline{__________} \text{ Hz} \), \( f_3 = \underline{__________} \text{ Hz} \), and \( f_5 = \underline{__________} \text{ Hz} \).

P4. A singer sounds the note E\(_3\) (165 Hz) leading to the emission of \underline{__________} air puffs per second. Using the triangular waveform, we can estimate that each puff of air contains 2.0 cm\(^3\) (2.0 \times 10^{-3} \text{ liters}) , which leads to a rate of air emission of \underline{__________} liters per second.

P5. A trained singer can release 4.0 liters of air from his/her lungs after each deep breath. At the rate of 0.33 liters per second, the singer can sustain the E\(_3\) note for \underline{__________} seconds on a single breath.

P6. Assume that a “singer’s formant” at 3000 Hz is due to a resonance on part of the larynx above the vocal cords. Using a cylindrical-closed-pipe model for the upper-larynx tube, we estimate the length of this region to be \underline{__________} m or \underline{__________} cm.

P7. According to Rossing (see Fig. 17.13, page 383), a pressure of 4000 N/m\(^2\) (loud singing) will produce a sound loudness level of about 120 dB. The sound intensity, \( I \) (in W/m\(^2\)), that corresponds to this sound loudness level (in dB), is \underline{__________} W/m\(^2\).

P8. Assume that the area of the mouth opening is 20 cm\(^2\) or 2.0 \times 10^{-3} \text{ m}^2. For loud singing at an intensity of 1.0 W/m\(^2\), the total radiated sound power = \underline{__________} W.