PHYS207 Exam 2 Solutions

Problem 1: [12 points]
a) why is the cochlea shaped like a snail?
To save space (to fit in the space available; as with trumpet, tuba etc, it works as well as a straight tube would)

b) what information does the brain use to determine the frequency of the sound?
From the distribution of the signals from the neural fibers leading from the hair cells (high frequency signals peak near the oval window (entrance, base), the low frequency signals peak close to the apex (the end of the basilar membrane)

c) is the saxophone reed “hard” or “soft”, and why?
It is “soft” : its frequency is influenced by the feedback from reflections off the end of the air column. (so the reflections purify the vibrations and also make it possible to produce many different notes with the same reed).

d) do the vocal folds function as hard or as soft reeds, and why?
They function as hard reeds: their frequency is given solely by the properties of the folds, not influenced by the resonance in the mouth and nasal cavities (You can still produce many different notes – it is as if you were constantly changing the reed by the many sophisticated muscles involved. Also: the resonances = “formants” - still very much influence the spectrum and therefore the sound quality!)

Also note that when you touch them, clarinet reeds feel hard, and vocal folds feel soft :-)

e) what is the “critical distance” in room acoustics?
Re is the distance from the source at which the intensities of the (diminishing) direct sound and the (uniform) reverberant sound are equal.

f) Consider the following concepts:

(Sound Intensity)   Loudness level   (Sound Intensity Level)   Loudness

Circle the one(s) that are **objective** (this means that the non-circled one(s) are **subjective**)

Problem 2: [10 points]
You are listening to your favored music at 50 phons at 120 Hz as well as at 4 kHz. When your parents leave, you increase the sound intensity by a factor of 100 (independent of frequency). Determine the resulting Intensity, Sound Intensity Level, Loudness Level and Loudness at the two frequencies, and compare with the original values. Present your results in a Summary Table:

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120 Hz</td>
<td>4 kHz</td>
</tr>
<tr>
<td>I</td>
<td>7.9 × 10^-6</td>
<td>6.3 × 10^-8</td>
</tr>
<tr>
<td>SIL</td>
<td>69</td>
<td>48</td>
</tr>
<tr>
<td>LL</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>L</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

LL and SIL from the graph, L from \( L = 2^{\text{LL}-40/10} \) and I from \( I = 10^{-12} \times \text{10^{SIL/10}} \)
Problem 3: [8 points] If one clarinet produces SIL of 62 dB and you take several of them (incoherent, all producing the same SIL):

a1) what will be the SIL if you have 5 of them?

\[ \text{SIL} = 10 \log 5 + 62 = 69 \text{ dB} \]

b2) how many you need to produce 74.3 dB?

\[ N = 10^{(74.3 - 62)/10} = 17 \]

b) if you (by some miracle) manage to get 5 of such clarinetists to be coherent, what will be the maximum and minimum SIL?

For a constructive interference (all 5 sources in “phase”) you get the

Maximum = 62 + 10 \log 5^2 = 76.9 \text{ dB}

Minimum is obtained when and where amplitude is zero due to the destructive interference, so \( I = 0 \)

(and SIL is not really defined, or equal to the “negative infinity”)

Problem 4: [12 points] A room of dimensions 20x30x15 meter has a large 15x 12 meter) glass sliding door in one pf the large walls; the door is closed. The reverberation is measured to be 5.37 seconds both at 4 kHz as well as 125 Hz. Then something is done to the glass door, and reverberation decreases to 3.82 seconds at 4 kHz Hz but increases to 6.25 seconds at 125 Hz.

What has been done to the glass door?

From RT = .161V/A we get

\[ A(\text{old}) = 0.161 \times 20 \times 30 \times 15 / 5.37 = 270 \text{ m}^2; \text{ this includes all surfaces, all items and air.} \]

Then the only change that happened was adding something and removing glass, both over the surface of the door, and therefore \( A(\text{new}) - A(\text{old}) = S(\text{door})(\text{alpha(new)} - \text{alpha(old)}) \) and we get:

\[
A(\text{new at 125 Hz}) - A(\text{old}) = 0.161 \times 20 \times 30 \times 15 / 6.25 - 270 = 232 - 270 = 12 \times 15 x (\text{alpha(new)} - 0.35)
\]

\[
A(\text{new at 4 kHz}) - A(\text{old}) = 0.161 \times 20 \times 30 \times 15 / 3.82 - 270 = 379 - 270 = 12 \times 15 x (\text{alpha(new)} - 0.04)
\]

And

\[
\text{alpha(new at 125 Hz)} = 0.35 + (-38)/12/15 = 0.14
\]

\[
\text{alpha(new at 4 kHz)} = 0.04 + 109/12/15 = 0.65
\]

From the Table we see that these are the absorption coefficients of heavy drapery – so they covered the door with it (“the curtain was drawn”).

(Note that this is essentially identical to the problem in your Homework).