Sound

I. Basic Concepts

1. Sound is a _____ _____ _____ in air.

2. The source of sound is a _____ _____.

3. Instead of plotting the displacement of the air molecules, we usually plot _____ in air _____ because this is what we can most easily measure.

4. There is a quarter wavelength shift between the two plots. Maximum and minimum _____ occurs at the displacement nodes.

5. Compression corresponds to _____ _____ and expansion (rarefraction) corresponds to _____ _____.
6. The speed of a sound wave depends slightly on temperature since the density of the gas changes.

For the standard temperature of 20° C, we have the speed of sound as 343 m/s.

II. Loudness

1. Loudness deals with the sensation in the consciousness of a human being. It is related to the physically measurable quantity, _____, but also deals with our hearing detection system.
2. Humans can hear sounds whose intensity varies between _____ and _____.

3. To have such a wide range of hearing, our auditory system is _____ rather than _____. The trade- off is that we are not as sensitive to changes in intensity. It takes a 10 x change in

intensity of sound for us to sense a change of 2 in loudness.

4. Sound level, β, is a measure of loudness and is measured in decibel (1/10 of a 'bel' which is named after Alexander Graham Bell).

5. The equation which relates sound level to intensity is:

   where the reference intensity, I_0, is taken to be the threshold of human hearing (1.0×10^{-12} W/m^2).

Example: A) If the intensity of a sound wave changes by a factor of 10, what is the change in the sound level? B) What is the approximate change in the sound level if the intensity changed by a factor of 2?

6. Humans are only sensitive to changes in sound level if they are at least 1 db. This corresponds to changes in sound intensity of approximately 30% or more depending on the human.

7. Sound falls off with distance as the energy of the wave is spread out over a larger area. For an open area, the intensity initially falls off as $1/r^2$ as expected for a point source as energy spreads out over the larger surface area of a sphere. At large distances, it falls off faster due to energy lost due to the irregular motion of air molecules.

III. Pitch

1. Pitch is the human sensation related to the _____ of a sound.
2. Best human ears can hear frequencies between _____ and _____ . This is called the audible range.
3. In Music, going up or down one Octave means changing the frequency by a factor of _____.

Example: Middle C has a frequency of 262 Hz. What is the frequency of C one Octave higher?

IV. Air Tube Instruments

If the diameter of the tube is small in comparison with the length of a tube then the pressure node (displacement antinode) will be approximately at the location of an open end of a tubed instrument.

A. Open Tube (both ends are open)

Wavelength and frequency formulas are the same as for standing waves on string with all harmonic frequencies allowed.

B. Closed Tube (one end of tube is closed)

1. Fundamental frequency is half of fundamental frequency for an open tube instrument.

2. Only odd harmonic frequencies are allowed.

V. Sound Quality

Sound quality is the ability of humans to detect differences between different instruments including humans. Instruments produce not only the fundamental frequency, but overtones of various amplitudes. The total sound is the superposition (addition) of these waves which makes sounds different (what we call sound quality). The musical terms are timbre and tone quality.

VI. Beats

1. Beats is a change in amplitude over time due to interference between two waves of approximately the same amplitude which differ slightly in frequency.

2. Beat frequency is given by the formula:

Example: If one clarinet plays Middle C with frequency 262 Hz and the other clarinet that is slightly out of tune produces a frequency of 265 Hz, what is the beat frequency produced?