Physics of Music
Physics 341
Assignment 4- solutions

Problems 3 5 6 were asked in assignment 3, so the solutions are there. The marking will be of questions 1 2 4 7

1) In the graph of dB versus frequency,

i) What frequencies correspond to -30dB? To -5dB?
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What pitches (including names) correspond to these frequencies?

ii)What dB correspond to 1700 Hz? 400Hz? 6500Hz? What pitches correspond to these frequencies? (use the nearest letter name, including ♯ or ♭)

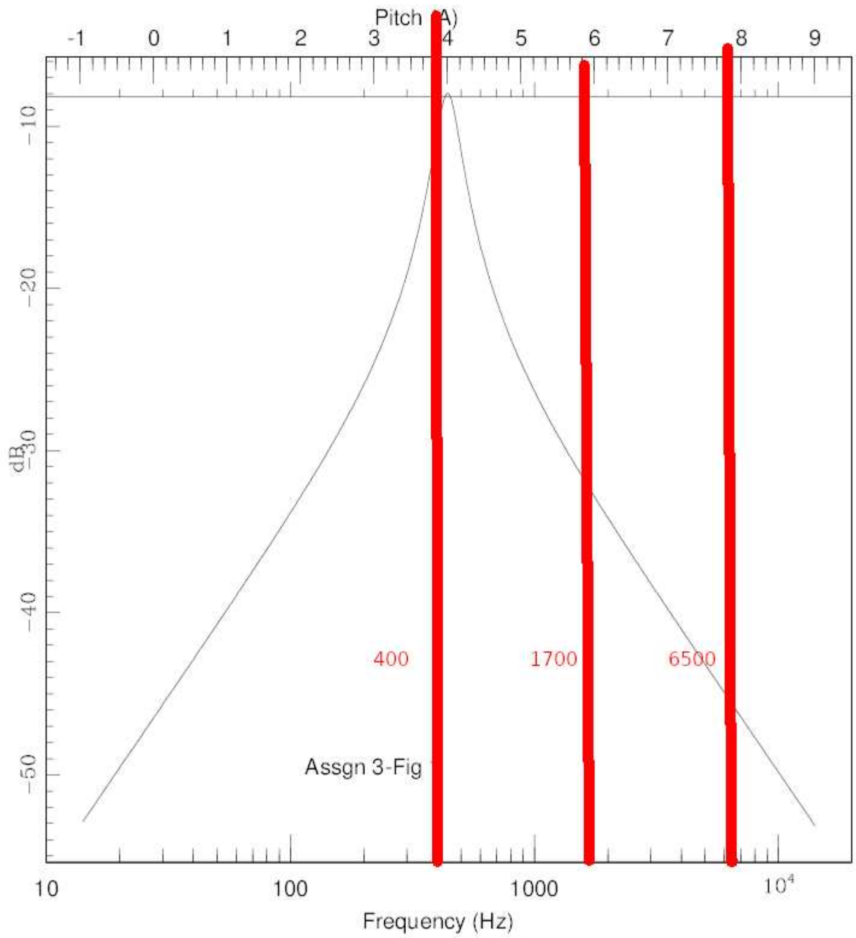

Figure 1

a)There are in first case two frequencies which correspond to this values of the dB response.

-30dB$\rightarrow$ 19.5Hz, 11000Hz

For -5dB on the other hand, there is no frequency which corresponds to it. It is off the top of the graph.

The easiest way to find the pitches is to look at the pitch scale on the top of the graph– 19.5Hz is just under 6 semitones (3 tones) above A_{-1}. It it lies just under an augmented 4th or a dimished 5th above A_-1, The name of the note would be $D_0\sharp$ or $E_0\flat$.

11000Hz lies just above 6 semitones above A_8 and would again be either $D_9\sharp$ or $E_9\flat$

b)The dB cooresponding to 400, 1700, 6500 frequencies are all close to around G (2 semitones less than A4 or 392) and G# (1 semitone less). Two octabes higher would be G6 (1568Hz) and G6# (1660Hz) while 4 octaves higher would be G8 (6272Hz) and G8# (6640 Hz) . G4, G#6,G#8 are probably closest. (between G and G# is probably OK. From the graph, anything between G and G# would be OK.

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Note that this graph is the graph of the "resonance response" of the energy (not amplitude) of an oscillator to an external driving force which has the same amplitude at each frequency. Note the 6 dB per octave fall off in the energy on either side of the resonant frequency (which occurs at 440 Hz).

2) I want to tune one string 2 Hz below another. How could I do this by listening to the two strings together?

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if one has two sounds at different frequencies which are within the critical band, then those two frequencies produce beats on the basilar membrane. Ie, the signal sent to the brain is louder and softer at a frequency which is the difference in frequency of the two sounds. In this case the beats would be at 2 Hz. You tune the one string until you hear the amplitude getting lounder then softer twice a second.

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3) The critical band is the range of frequencies around which the vibration on the basilar membrane overlaps (ie, if one has two frequencies, the widths of the region which which each causes to vibrate overlap with each other). This is taken to roughly be a minor third (ie, if two frequencies differ by less than a minor third, their regions of membrane excitation overlap). Consider the series of harmonics of a note. By which harmonic do successive harmonics have overlapping excitations on the basilar membrane?

4) 1) In graph 1, add the two waves to get the composite wave.

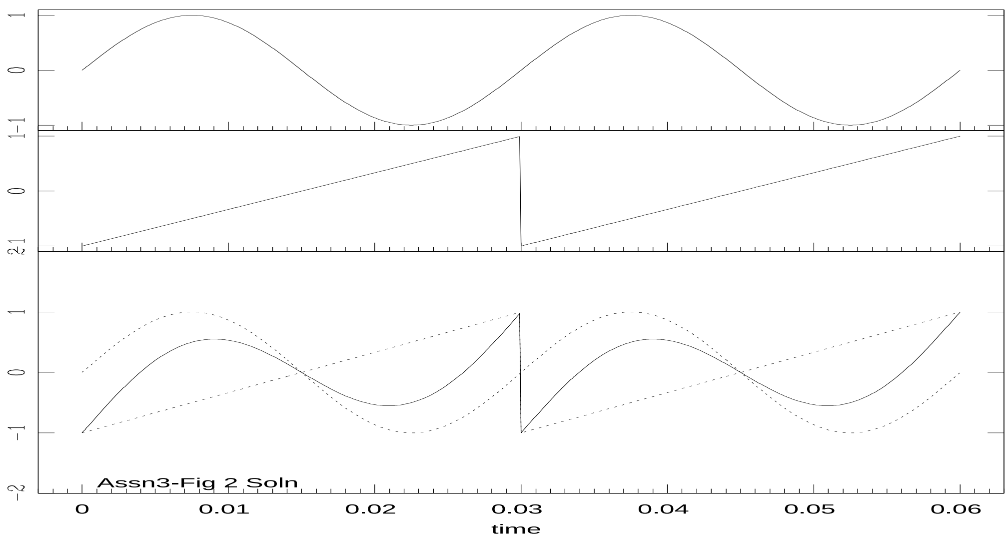

Figure 3

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Adding the waves. Note that the most important issue is that the bottom of the two to be added has a very sudden change. One must make sure that one selects a fine wenough set of points to plot in order to capture the effect of this sudden change in the sum graph.

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5)a) How much sharper or flatter (give a ratio) is a just major third (5/4) to two Pythagorian whole tones?

b)Three major thirds (four semitones) could be said to be an octave (twelve semitones). How mistuned would that octave be if each of those major thirds were just major thirds?

6 a)I attended the Marriage of Figaro a few years ago, and found that hearing the bass while he was singing his lower notes was much more difficult than hearing the tenors and the women. Could there be some Physics reason for this? What is it?

b) Why is an (unpowered) megaphone useful (consider the size of the radiating area)? Why do singers tend to sing with their mouths wide open? (It is not for the looks!)

c) Why, when you scream for help, do you open your mouth wide and scream at a high pitch?

7. Why, when you take off your earphones and lay them on the table, do you suddenly stop hearing the bass, and all you hear is a very tinny high pitched sound?

When the earphones are in the ear, the motion of the earphone diaphram pushes directly on the air in the ear. There is not efficiency problem (the effeciancy is 1 for all of the frequencies) When it is out of the ear, the efficiency is usual speaker efficiency, and because it is so small, the speaker resonance is high in frequency. this means that the low frequencies never get to the ear. The knee frequency of the speaker diaphram is high (the diamaer is a few mm at best. Ie, only the high frequencies get out of the earphone and get to you ear.