Physics of Music
Physics 341
Assignment 4

1) In the graph of dB versus frequency,

i) What frequencies correspond to -30dB? To -5dB?

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 ♭)

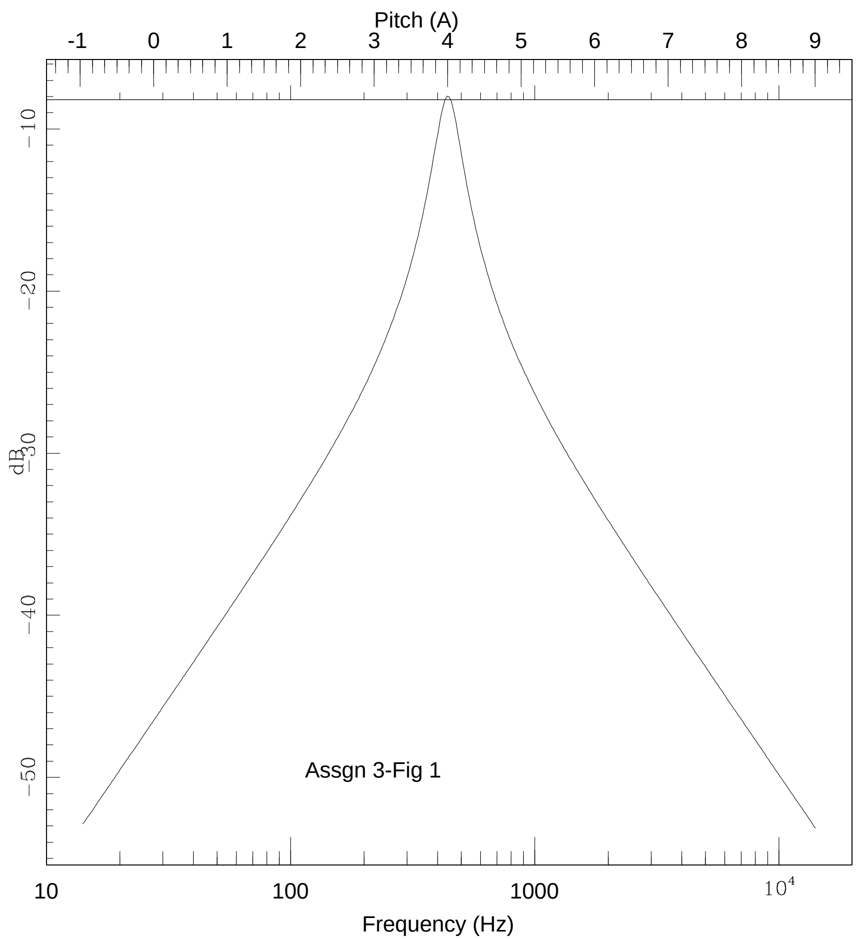


Figure 1

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).

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 $E_9\flat$

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

Two notes when played together will, if their frequencies are not too different, produce beats– variations in the loudness of the sound. The rate of loudness variation is just the difference in frequency. Thus if two notes are separated by 2Hz, their loudness will go from lound to soft to loud again twice per second. Tuning the two strings until you hear that variation in sound occuring 2 per secont (120 per minute which you can set on a metronome) will ensure that the strings are tuned to within 2 Hz of each other. You would have to pluck them successively to make sure the string you wanted is 2Hz lower rather than two Hz higher, since the beats would be the same for both cases.

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?

Successive notes of the harmonics– the nth harmonic and the $n+1$st harmonic have a frequency ration of $\frac{n+1}{n}$. Thus the fifth and sixth harmonics have a frequency ratio of $\frac{6}{5}$. The frequency ratio of a minor third is $\frac{6}{5}$ in the just tuning. Ie, by the fifth harmonic the successive harmonics are overlaping, the next harmonic is overlaping. This means that the two notes begin to excite the same region on the membrane, and the same cells send signals to the brain. There will in general be some beating (interference) between the two. However the brain often can still differentiate the two notes, but not always.

There is a very interesting demonstration at

http://languagelog.ldc.upenn.edu/nll/?p=2074#more-2074

where a major and minor chord can be discriminated by some people and not by others. Is this a case where the critical band of some people overlap more than for others? In each case the chord has an interval of a minor third and a major third, but in opposite order (in pitch progression), and some people have real problems telling which is which (and others have no trouble at all). The evidence seems to be that this is not a matter of musical training– some good musicians cannot tell and some naive listeners can.

4) In graph 1, estimate what the highest harmonic which would be needed to make up the complex wave form?

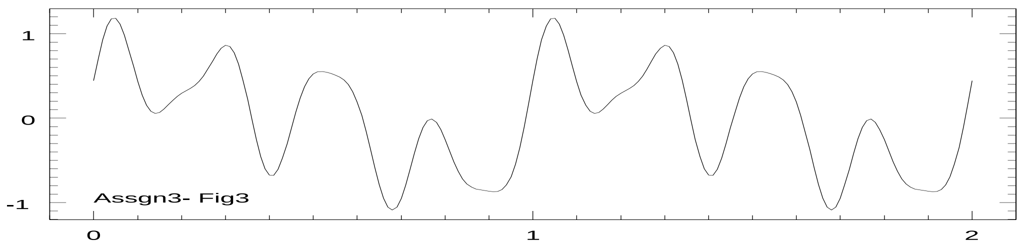


Figure 1

This is a tough one. There ae four clear peaks in one period (of 1 sec). But looking more closely, at about .25 sec there is clearly a peak trying to come out. Similarly at .6 to .8 sec, it looks like the some of two peaks, rather than it just being one peak. This suggests that there highest harmonic is at least the sixth. If we look at the graph from ..65 to .8 this looks like a clear single up and down, with a period of about .15 sec. This would suggest that the max freq is something like 1/6 (1.67) to 1/7 (1.43) of a sec So the highest mode would we something like the 6th or seventh.

5) 1) In graph 2, add the two waves to get the composite wave.

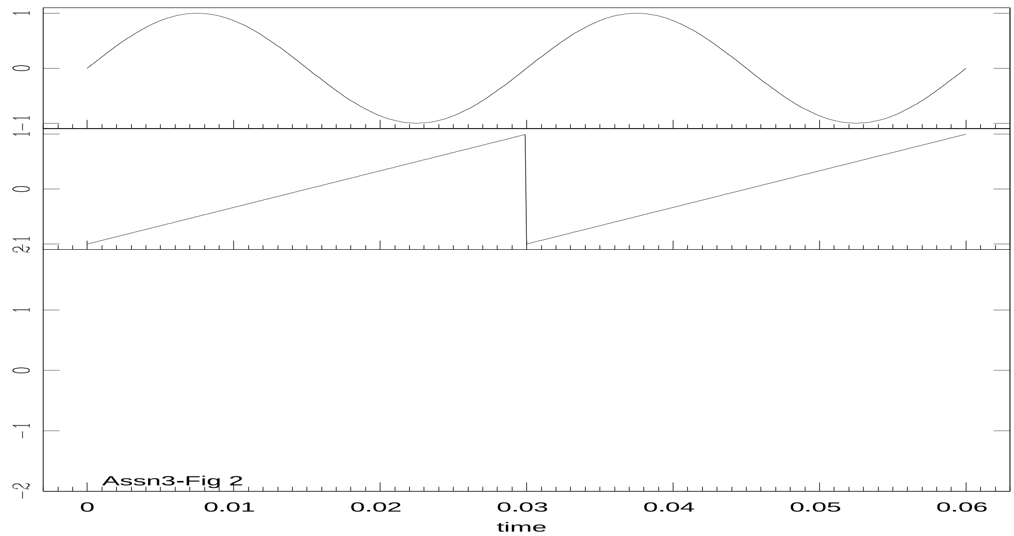
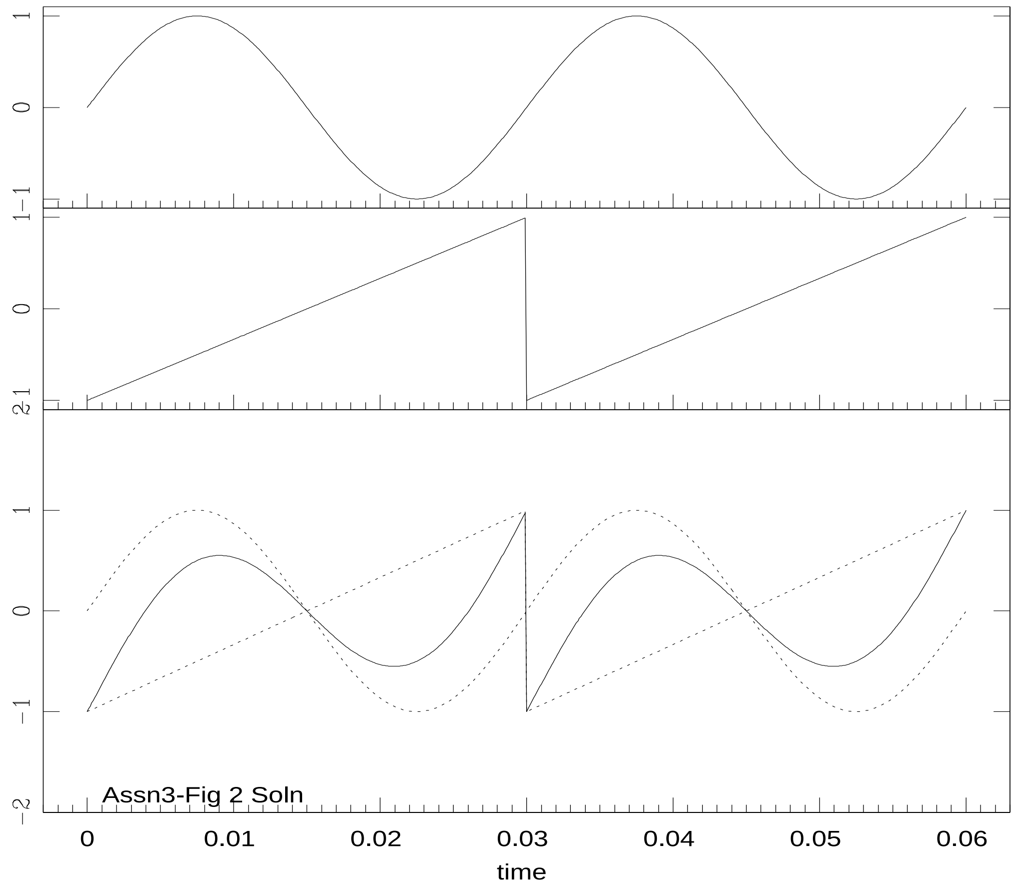


Figure 2



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.

6) A rock concert is going on in Deer Lake Park. Leigh Palmer, at a distance of 1km from the concert measures the intensity of the sound at his house at 80dB. How loud will the sound be 10m from the speakers, where many of the audience will be located?

Assuming the concert lasts for an hour, what intensity should the sound be at 10m from the speakers in order that it comply with the BC Workman's Compensation Board limits on noise in the workplace? What would now be the intensity at Palmer's house?

(Under WCB regulations, the average intensity over 8 hours must be less than 80dB. If all of that exposure takes place in 1 hour, what intensity can the concert be at?)

The intensity of the sound dies off as the square of the distance. Palmer's house is 100 times further away from the stage than the people attending the concert, and thus the intensity will be the square of that, which is 10000 times less. Since each factor of 10 represents 10dB, and this is four factors of 10, this represents 40dB. Thus at Palmer's house the sound is 40 dB less than at near the stage. The sound level at the stage would thus be 80+40=120 dB.

If the sound level at the stage were 0 dB for 7 hours, and the aveage were 80dB over 8 hours, then the intensity could be 8 times louder that 80dB over that one hour. 8 times is 9dB so the intesity on stage would have to be less than 89dB duing that hour. The intensity at Palmer's would then be 40dB less of 49dB. (That is pretty quite). This also illustrates why WCB regulations are almost always ignored by things like rock concerts. Also they tend to reponsd to complaints, and then come out to measure the intensity. By that time the concert is over. Mind you a whole buch of attendees are deafened, but...