Physics of Music
Physics 341
Assignment 3

1)a) How many ocataves and semitones are the two notes with frequency 300Hz and 2700Hz apart?

$$2x300 = 600 \tag{1}$$
$$2x600 = 1200 \tag{2}$$
$$2x1200 = 2400 \tag{3}$$

That is three multiples of 2, or three octaves. The ratio between the final note and that final octave is

$$2700/2400 = 1.125 \tag{4}$$

which is a tiny bit larger than 2 semitones, or one tone. (In fact this is a ratio of 9/8 which is the Pythagorean tone)

b)A soprano sings two notes (in succession) a perfect fifth apart. What is the difference in frequency between the two notes if the lower one is sung at 450Hz.

A perfect fifth is a frequency ration of 3/2 (Pythagorian) or 1.4983 equal temperament. Thus the higher note will be $\frac{3}{2}450 = 675$Hz or in equal temperament $1.4983x450 = 674.2Hz$.

2)a) A workman is exposed to a sound of 60dB for 7 hours, and 100dB for one hour without hearing protection. What is the average energy rate of the sound that he received during the course of the day? The Workman's compensation says that if the average energy rate is higher that 80dB during 8 hours, hearing protection must be provided. Is the company in compliance?

The second sound is 40dB luder than the first which is 10000 times louder. Thus for 7 hours, the sound is a certain level, and the last hour it is 10000 times as much. On average it is therefor (10000+7)/8 which is 40dB-9dB=31dB louder than 60dB. Ie the average is 91 dB which is much higher than the limit.

b) The standard in BC for Railway workers is that the average noise level must not exceed 87dB for an 8 hour day. BC mandates the 3dB rule, namely that the time of exposure must be halved for each 3dB rise in the average noise level. How long could a railway worker work in a place (eg a disco) with an average noise level of 120dB? In Ontario, the requirement is that the worker is allowed to be exposed to 90 dB for an 8 hour day, and that the time is halved for each 5dB rise in noise level. How long would a Ontario worker be allowed to work in that same disco.

In BC, that 120dB sound is 33dB above the limit, which is 11 factors of 3dB. Thus you need to divide 8 hours by two eleven times, which is very

close to dividing by 2000 times. Ie, the worker could be in that disco only (8x60x60)/2000=14.4 seconds.(15 seconds)

In Ontario, that sound is just 30dB above the limit, which is 6 times the 5dB halving time. The limit would be 8hr/(2x2x2x2x2x2)=1/8 hr, or 7.5 min. which is about 30 times as long as the BC worker could be there.

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

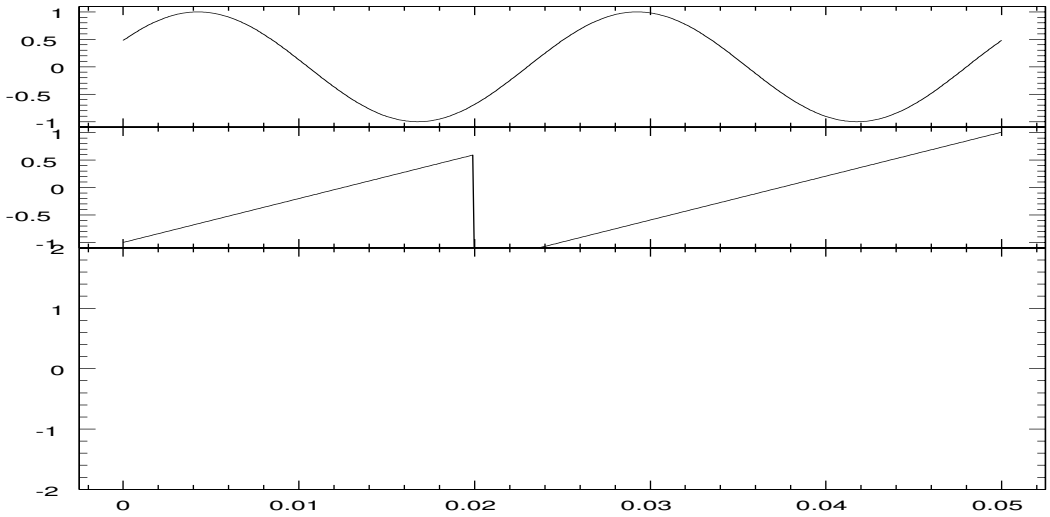
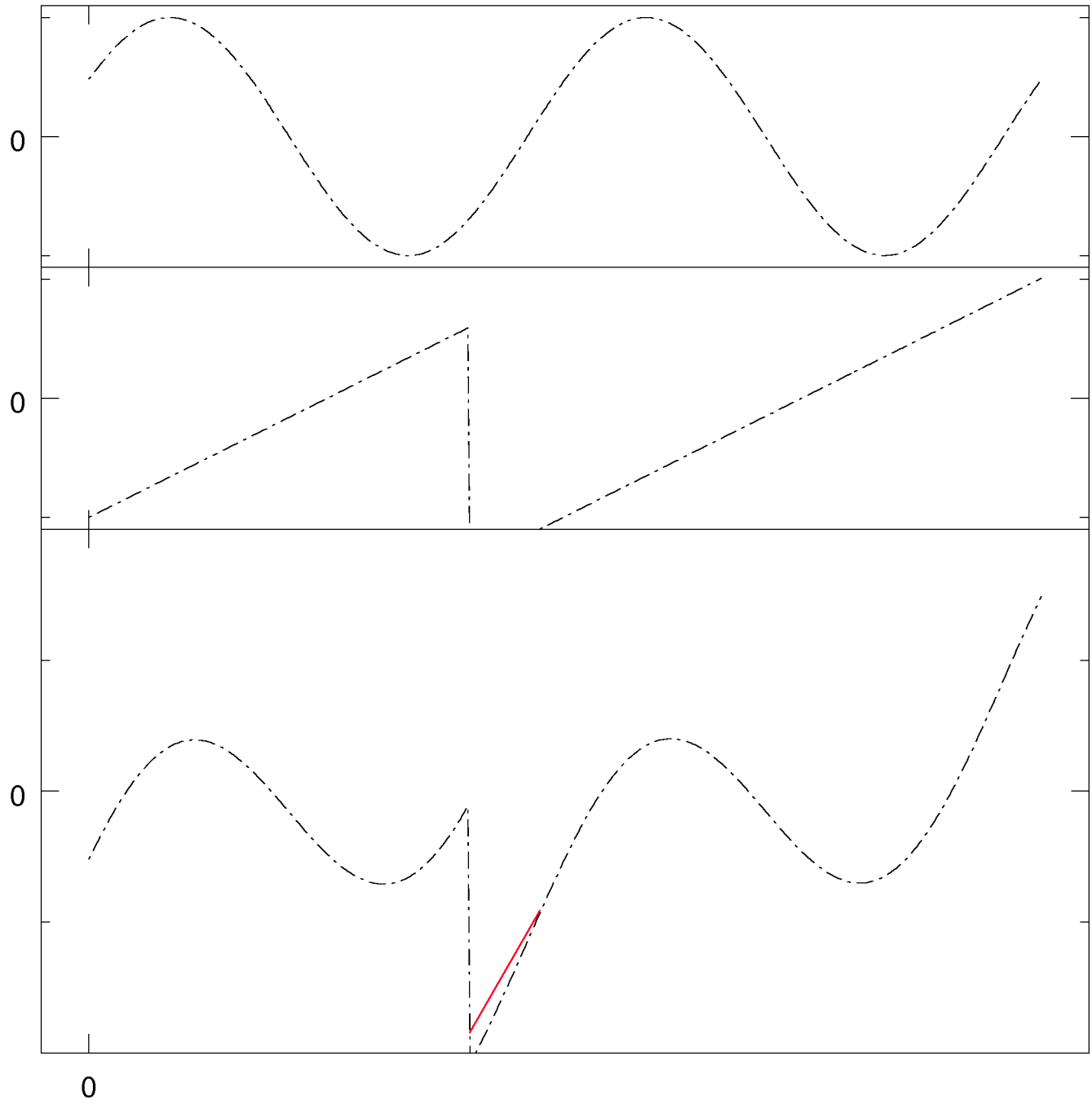


Figure 1

It is not clear if the one curve was cut off by the bottom of the graph or should be taken as running along the bottom edge. Here are the two possible solutions.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4) When I sing in bed, after I stop it seems that the bed is singing a note back to me. What is going on here?

Most of the time when something makes a noise when you make a noise at it, it is because of resonance. (Now when you shout at your boy/girl frind and they shout back, one might be able to call that metaphorical resonance, but the physics is very different.) The notes from my mattress must mean that there is something which vibrates with a fairly high Q within the mattress, and teh only possibility is the springs. Since my singing is at at least 100 Hz, the mattress kept singing for about 20 cycles, and thus had a Q of about 80. This very undamped which is what make the effect so surprizing.

5) 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.

6) The sun at high noon in the tropics shines on the ground with an intensity of $1kW/m^2$. If this were sound instead of light, what would be the intensity of the sound in dB on the standard scale with the reference of 10^{-12} W/m^2?

The sun is $1000w/m^2$. To get to that starting at $10^{-12}w/m^2$ you have to multiply by 10 15 times. Each factor of 10 is 10dB so after 15 of them, that is 150dB. It would be a horrendously loud sound coming from the sun. Fortunately we see it rather than hear it. (our eyes are much less sensitive than our ears to the energy coming in to them) If the whole sky were the same energy as the sun's surface as seen from earth, the level would be about the equivalent of 195dB in sound energy, which is also the approximate level in a bomb blast (pressure variations of about 1 atmosphere pressure).