I547: Audio Music Processing
Homework 2 Solutions

1. Using R, generate pitches at frequencies $f, 2f, 3f \dots 8f$ where $f = 440 * 2^{(-9/12)}$ Hz (middle c). For each pitch give the name of the note (eg. c,d,e ...) and compare the frequency with the frequency of the equal tempered approximation of the pitch giving the ratio of frequences (which should be near 1).

   Solution: pitches are c, c', g', c'', e'', g'', bflat'', c'''. To compare with equal tempered versions of the same notes:

```
f =  440*2^(-9/12)
for (h in 1:8) {
  g = h*f
  hs = round(12 * log2(g/440))  # halfsteps above f
  ghat = 440*2^(h/12)           # the equal tempered freq
  print(g/ghat)                 # this is the actual ratio of frequencies
}
```

2. In R two vectors x and y can be "concatenated" (strung together) using the notation

```
>  z = c(x, y)
```

   the result is a vector whose length is the sum of the two lengths. Use this to create the first 10 notes of "Amazing Grace" in the key of C. Create the correct rhythm as well. The pitches for the melody are (in one of the many variations) c(G,C,E,D,C,E,D,C,A,G) while the relative note lengths are c(1,2,1/2,1/3,1/6,2,1,2,1,2).

3. To simulate the bagpipes, add a low "drone" (long held notes of c and g) to your melody. Optional: Add grace notes and use apprpriate tone color to simulate the feel of the bagpipes. Be prepared to play your example in class.

4. Suppose we generate a function

$$f(t) = a_1 \cos(2\pi f t + \phi_1) + a_2 \cos(2\pi 2 f t + \phi_2) + \dots + a_{10} \cos(2\pi 10 f t + \phi_{10})$$

   where $a_1 \dots, a_{10}$ are the amplitudes and $\phi_1 \dots, \phi_{10}$ are the phases. Give the perceived pitch (in Hz) if we set

   (a) $a_1 = a_3 = a_5 = a_7 = a_9 = 0$ and the others are 1.
   all harmonics have are 2f-periodic, so the sum is too

   (b) all to zero except $a_3 = a_6 = a_9 = 1$
   hear freq 3f for same reason

   (c) $a_1 = 0$ and all others 1.
   all harmonics are f-periodic, so the sum will still be f-periodic. We recognize the periodicity even if no energy at the fundamental frequency.

   In each of the cases explain why this is consistent with the ideas we have learned.

5. **An expressive octave leap** We want to create a somewhat expressive sounding leap of an octave. (Think of "Somewhere over the Rainbow." Our frequency must not suddenly jump an octave, but rather have a rapid *glissando* (smooth pitch change) and arrive at the top note with pitch vibrato.

   (a) Create your pitch function, starting at the lower octave note, rising quickly, and sustaining the upper octave with vibrato, sampled at 16KHz and plot it.

   (b) Use this function to create expressive leap. Be prepared to demonstrate your sound in class.

```
sr = 16000
p1 = rep(440,1*sr)
p2 = seq(from=440,to=880,length=.5*sr)
p3 = 880 + 5*sin(5*seq(0,2,by=1/sr))
pitch = c(p1,p2,p3)
g = sin(cumsum(2*pi*pitch/sr))
```

6. Create a pitch vibrato around 440 Hz of width 10 Hz that begins at a rate of 2 Hz and gradually increases to a rate of 10 Hz. The entire sound should be 10 secs. long. Be prepared to demonstrate your result in class.

```
sr = 16000
rate = seq(from=2,to=10,10*sr)
freq = sin(2*pi*cumsum(rate)/sr)
g = sin(cumsum(freq)/sr)
```