% In-Lecture Assignment #1 on Monday, Feb. 11, 2019

% (a) Using the Matlab code below that generates a cosine signal
% $x_A(t) = \cos(2\pi f_A t)$ with $f_A = 440$ Hz for 3 seconds at sampling rate $f_s = 8000$ Hz:

```
fs = 8000;          % sampling rate
Ts = 1/fs;          % sampling time
tmax = 3;           % 3 seconds
t = 0 : Ts : tmax;
fA = 440;
xA = cos(2*pi*fA*t);
```

% add to the above code to create and play an A major chord of A, C# and E
% $x(t) = x_A(t) + x_{C\#}(t) + x_E(t)$
% where $f_{C\#} = 554$ Hz and $f_E = 660$ Hz. Comment on what you hear.

% (b) Plot the spectrogram of the A major chord and comment on what you see:

```
figure;
spectrogram(x, hamming(1024), 512, 1024, fs, 'yaxis');
```

% (c) Add dampening to the amplitude to mimic the release of the note over time.
% Play the dampened note and plot its spectrogram.
% What has changed vs. parts (a) and (b)?

% (d) Copy your answers for the above parts into the In-Lecture Work #1 page on Canvas.

% Solution

% (a) Generate the notes for an A major chord

```
fs = 8000;          % sampling rate (a standard audio rate)
Ts = 1/fs;          % sampling time
tmax = 3;           % 3 seconds
t = 0 : Ts : tmax;
fA = 440;
xA = cos(2*pi*fA*t);
fCsharp = 544;   % '#' is not a valid character for a Matlab variable
xCsharp = cos(2*pi*fCsharp*t);
fE = 660;
xE = cos(2*pi*fE*t);
x = xA + xCsharp + xE;
sound(x, fs);
pause(tmax+1);  % Pauses until playback is finished
soundsc(x, fs);
pause(tmax+1);            % Pauses until playback is finished
```

% I hear three notes being played.

% The sound command will clip any amplitude value greater than 1 to 1, and
% any amplitude value less than -1 to -1. This clipping sounds like distortion/noise.
% The clipping affects 41% of the samples (see Optional part for (a) below).

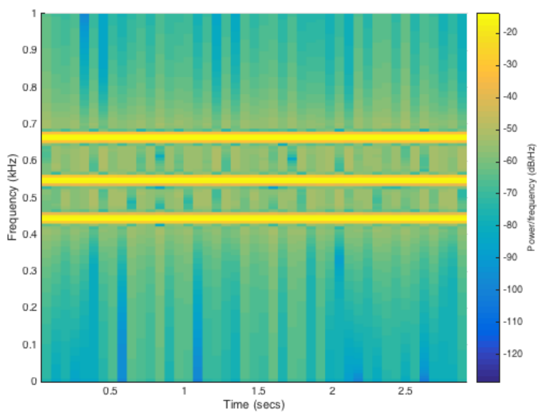
% The soundsc command will make sure that amplitude values are not clipped by

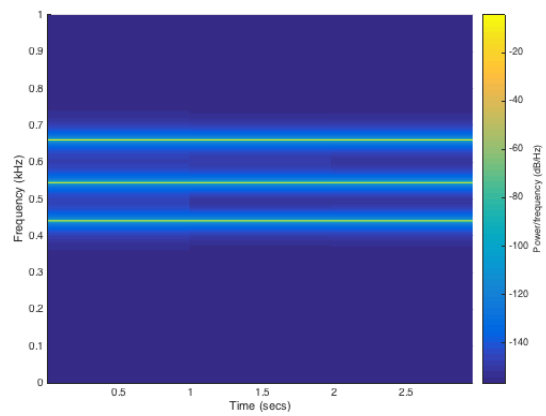
% mapping the range of amplitude values [a, b] to the range [-1, 1] before playback.
% Playback with soundsc sounds like 3 principal frequencies w/o much distortion/noise.

% An A major chord played as a sum of three note frequencies does not sound pleasant.
% When a musical instrument plays a note, the frequency for that note is played along
% with harmonics of that note and noise/distortion characteristic of the instrument.

% (b) Plot the time-frequency components of x(t) using the spectrogram command.
```
spectrogram(x, hamming(1024), 512, 1024, fs, 'yaxis');
ylim( [0 1] );          % Zoom the frequency axis to 0-1 kHz range
```

% The above code generates the spectrogram on the left.





% The spectrogram contains three vertical
% lines across the time axis at principal frequencies 440 Hz (A4), 544 Hz (C#)
% and 660 Hz (E). Each vertical line represents a small range of frequencies.

% (c)
```
x = x .* exp(-2*t/tmax);
soundsc(x, fs);
figure;
spectrogram(x, hamming(1024), 512, 1024, fs, 'yaxis');
```

% ***Optional for (a):*** The Matlab command x > 1 will return a vector that is the same
% length of x with a 1 entry if that component of x is greater than 1 and 0 otherwise.
% We can then sum up the elements of 0s and 1s using the sum command:
```
sum( x > 1)
```
% returns the number of samples in x whose amplitudes are greater than 1.
```
sum(x < -1)
```
% The following returns the number of samples in x whose amplitudes are less than -1.
```
sum( x > 1) + sum( x < -1)
```
% gives 9949 samples out of the 24000 samples of x.

% ***Optional for (b).*** Increasing the number of samples in a segment will increase the
% frequency resolution, and decreasing the shift from one segment to the next will
% give us more time resolution. Code below plots the spectrogram on the above right.
```
figure;
spectrogram(x, hamming(8000), 128, 8000, fs, 'yaxis');
ylim( [0 1] );
```