ELEG 4603/5173L Lab # 2
Discrete-Time Systems

1. Use the `conv()` function find the convolution sum of the following signals, and verify the results with your manual calculation.

   (a) $x(n) = \exp(-n)u(n)$, $h(n) = \exp(-2n)u(n)$

   (b) $x(n) = [1, 4, -2]$, $h(n) = [2, 0, 3, -1]$

2. Write your own Matlab function, `y = convsum(x, h)`, to calculate the convolution sum between two vectors, `x` and `h`, based on the definition of convolution sum. The inputs are two vectors, `x` and `h`, and the output vector `y` is the convolution sum between `x` and `y`. The result should be the same as the Matlab built-in function `conv( )`. (Use "`help function` to learn how to write a Matlab function). Repeat Problem 1 with your own `convsum()` function.

3. Delay and Echo. The following example showed how to load a wav file and play it with Matlab.

```
clear all
% read the file, Fs: sampling frequency
[data,Fs] = audioread('music.wav');

x_left = data(:, 1).';
x_right = data(:, 2).';

% Ts: sampling period
Ts = 1/Fs;

% normalize the sound to avoid clipping
x_left = x_left/max([abs(x_left), abs(x_right)]);
```

```
13 x_right = x_right/max([abs(x_left), abs(x_right)]);
14
15 % output = input
16 y = [x_left.', x_right.'];
17
18 % playback the sound
19 sound(y, Fs);
```

Consider a music piece is being played in a round theater where the orchestra is in the middle of two concentric circles and the walls on one half side are at a radial distances of 17.15 meters (corresponding to the inner circle) and 34.3 meters (corresponding to the outer circle) on the other side from the orchestra. The speed of sound is 343 meters/sec. The recorder is at the same location as the orchestra. The recorded signal is the original plus the echoes from the two walls, as

$$y(n) = x(n) + 0.8x(n - N_1) + 0.6x(n - N_2) \tag{1}$$

(a) What is the impulse response of the above system?

(b) If the sampling rate is 44.1 kbps, Find the values of N_1 and N_2.

(c) Implement the system by using convolution. Play the sound and compare it to the original piece. Try the system on both `female_voice.wav` and `music.wav`.

(d) Adjust the amplitude of the two reflected signals and see how that affect the sournd.

4. Impulse response of LTI system. A discrete-time LTI system is represented by the difference equation

$$y(n) = 0.15y(n - 2) + x(n) \tag{2}$$

(a) Write a Matlab code to find the impulse response of the system by setting $x(n) = \delta(n)$, and then recursivley calcuate the value of $y(n)$ by following the difference equation (**Hint**: The impulse response has infinite length. You only need to find the first 15 values of $h(n)$).

(b) Use the Matlab function `filter()` to get the impulse response. Compare the result with part (a). (**Hint**: use `help filter` to learn about the function `filter`. You can set the input vector as `x(n) = [1, zeros(1, 14)]`)