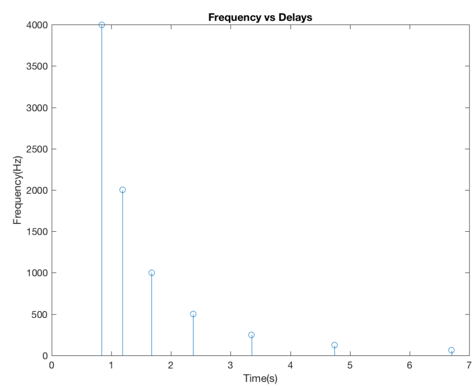
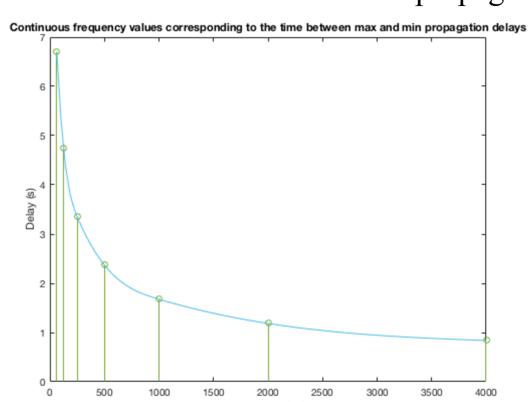
Acoustics Homework 4 and 5

1. A long and straight steel railroad track with a 4x4-inches cross section lying flat on the ground is hit vertically by a heavy hammer, generating an impulse-like disturbance which causes bending waves to travel down the track. The received signal is monitored with an ideal piezoelectric transducer attached on the track at 1-mile away from the source. Ignoring propagation attenuation and reflections:
    a. Calculate the bending wave propagation speed for the standard octave bands between 50 Hz and 5 kHz and the time delay between source and receiver corresponding to the standard octave center frequencies in the 50 Hz and 5 kHz band.

Frequency	**Speed**	**Delay**
62.5	239.9753	6.7049
125	339.3763	4.7411
250	479.9505	3.3524
500	678.7526	2.3705
1000	959.9011	1.6762
2000	1357.5051	1.1853
4000	1919.8022	0.83811



    b. Calculate and plot the continuous frequency values corresponding to the time between maximum and minimum propagation delays.



    c. Assuming that a track was excited with a perfect impulse, calculate and plot the time waveform of the received disturbance and provide it as a .WAV file.

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% Question 1

% Part A
% Calculate the bending wave propagation speed for the standard octave
bands
% between 50 Hz and 5 kHz and the time delay between source and
receiver
% corresponding to the standard octave center frequencies in the 50 Hz
and 5 kHz band.

base = 4*0.0254;
height = 4*0.0254;
rho = 7800;
SteelPropSpeed = 5000;
distance = 1609;

% Young's Modulus for Steel
E = rho*(SteelPropSpeed^2);

% Second moment of Intertia
I = base*(height^3)/12;

% Bending Stiffness
B = I*E;

% Mass per unit length
M = base*height*rho;

% Frequency of octave bands
f = [62.5 125 250 500 1000 2000 4000];

% Calculating angular frequency(w) for the octave bands
w = f.*(2*pi);

% Calculating propogation speed
PropogationSpeed = ((B/M)^.25).*(w.^.5);

% Calculating Delays
Delays = distance./PropogationSpeed;

disp('Frequency     Speed     Delay')
for ii = 1:length(f)
    freqdisp = num2str(f(ii));
    speeddisp = num2str(PropogationSpeed(ii));
    delaydisp = num2str(Delays(ii));
    disp([freqdisp '      ' speeddisp '      ' delaydisp]);
end

% Part B
figure(1)
stem(f, Delays);
hold on;
x = linspace(min(f), max(f), 100);
y = spline(f, Delays, x);
plot(x, y);
title('Continuous frequency values corresponding to the time between
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max and min propagation delays');
xlabel('Frequency (Hz)');
ylabel('Delay (s)');
```

2. Design an acoustic impedance measuring tube for measuring the acoustical properties of materials for frequencies extending from 60 Hz to 2 kHz.
   a. For a cylindrical tube determine the required tube diameter and minimum tube length.
      Tube Diameter is 0.099914 meters, and tube length is 2.8417 meters

```
c = 341;
Fmin = 60;
Fmax = 2000;
a = (1.841*c)/(2*pi*Fmax); %Bessel Function
TubeDiameter = a*2;
TubeLength = c/(Fmin*2);

disp(['Tube Diameter is ' num2str(TubeDiameter) ' meters, and tube
length is ' num2str(TubeLength) ' meters']);
```

   b. For a square cross-section tube determine the required square edge length and minimum tube length.
      Length of side of tube is 0.12056 meters, and length of tube 2.8417 meters

```
c = 341;
n = 1;
Fmax = 2000;
Fmin = 60;
a = (c*n*(2^0.5))/(2*Fmax); % Side of tube
L = c/(Fmin*2); % Length of tube - must be greater than max lambda / 2

disp(['Length of side of tube is ' num2str(a) ' meters, and length of
tube ' num2str(L) ' meters'])
```

3. The acoustic impedance tube designed in 1 above, was used to measure a particular solid material sample obtaining the following readings:

	62.5 Hz	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**
p_{max} (Pa rms)	20	20	20	18	30	28
p_{min} (Pa rms)	12	10.8	5	2	10	4
x_{max} (m)	2.4	1.36	0.74	0.06	0.185	0.11

xmax is the location of the obtained pressure maximum (pmax) readings, measured from the sample. For the sample under consideration, calculate the pressure minimum location closest to the sample, the magnitude and phase of the pressure reflection coefficient, r = Rejφ , and the corresponding power loss factor, β, and absorption coefficient, α, for the given frequencies.