1) Develop a Working Model (WM) simulation of a simple pendulum as shown in Notes\_07\_03 with angular motion of ±10 degrees of swing. Use m = 0.46 lbm, a = 3.7 inches and JG = 1.5 lbm.in2. Provide MATLAB graphs of angular position, velocity and acceleration as a function of time for at least 5 oscillations. Attach a screen shot of your mechanism. Determine period of oscillation from your graphs and calculate period of oscillation using Notes\_07\_03.

WM \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ CALC \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2) Produce a MATLAB phase plane plot of angular velocity as a function of angular position. Discuss the shape of this plot.

3) Provide a MATLAB FFT plot of frequency content for angular acceleration of your pendulum simulation using angular motion of ±10 degrees. Determine natural frequency and the period of oscillation from the FFT. Show your work.

fN \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ FFT \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4) Repeat part 3) for ±80 degrees of pendulum motion. Discuss the difference in the FFT plots.

fN \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ FFT \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**EXTRA CREDIT**

Provide a MATLAB plot of frequency content for piston acceleration from H03. Discuss where you would expect peaks in this plot.

% test\_fft.m - example use of FFT

% HJSIII - 20.04.06

clear

% read time domain data here

% must also define time step h

% alternately create synthetic signal for testing

% synthetic - 30 Hz sine, +/- 5 mm, 0.001 sec time step

h = 0.001; % time step [sec]

f\_synthetic = 30; % synthetic frequency [Hz]

x\_max = 5; % size synthetic signal [mm]

t = [ 0:(1999) ]' \* h; % synthetic time [sec]

x = x\_max \* sin( 2 \* pi \* f\_synthetic \* t ); % synthetic signal [mm]

% bottom - creating synthetic signal

% synthetic square wave

%x = sign( x );

% find number of samples and sampling frequency

n = length( x ); % number of samples

fs = 1 / h; % sampling frequency [Hz]

% FFT

% MATLAB FFT must be scaled by 2/n - DC component must be scaled scaled by 1/n

a = fft(x) \* 2 / n; % complex number - units [mm]

a(1) = a(1) / 2; % offset at frequency of 0 Hz [mm]

amp = abs( a ); % amplitude at each frequency [mm]

phase = angle( a ) \* 180 / pi; % phase angle [deg]

df = fs / n; % frequency resolution between spectral bands [Hz]

freq = [ 0:(n-1) ]' \* df; % all frequencies [Hz]

% find peaks and list

[ peaks, i\_locations ] = findpeaks( amp, 'MinPeakHeight', 0.01 ); % ignore tiny values

disp( ' ' )

disp( ' freq [Hz] peak [mm]' )

disp( [ freq(i\_locations) peaks ] ) % units [Hz] [mm]

% plot time domain, amplitude, phase

figure( 1 )

subplot( 3,1,1 )

 plot( t, x )

 xlabel( 'Time (sec)' )

 ylabel( 'Signal [mm]' )

subplot( 3,1,2 )

 plot( freq, amp )

 xlabel( 'Frequency [Hz]' )

 ylabel( 'Amplitude [mm]' )

subplot( 3,1,3 )

 plot( freq, phase )

 xlabel( 'Frequency [Hz]' )

 ylabel( 'Phase [deg]' )

% bottom - test\_fft