Laboratory 3 – Prelab
System Identification using Frequency Response

The frequency response plot you generated during laboratory 2 is the magnitude and phase of the transfer function evaluated at $j\omega$, as shown in Eq. 1

$$|H(j\omega)| = \frac{1/k}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} \tag{1}$$

Since we don't actually know the input force (we only know what we put in the Simulink model that controlled the hardware) we will have an unknown constant related to the force. Therefore, Eq. 2 can be written as

$$|H(j\omega)| = \frac{K}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} \tag{3}$$

In this task we will identify K, ω_n and ζ in two ways: 1) Minimize the cost function J using the magnitude, 2) minimize J using the magnitude in dB.

You will need two m-files:

File 1 - A Matlab script to set initial parameters and call "fminsearch" and make all the plots. Always plot your initial guess and your experimental data and then the final fit and the experimental data.

File 2 – A Matlab function that fminsearch uses to calculate the function it is minimizing.

An example of these files is shown below. Please try to understand these m-files because you will need to modify them for this and future labs.

File 1:

```
% load experimental data

clear
load freq_resp_data      % this loads the data file with variables freq (in
                           % Hz) and mag

% some initial values - picked at Random
K = 10;    % gain
zeta = 0.1;      % damping ratio guess
fn=2;    % natural frequency guess in Hz

%let's plot what this guess looks like (this is always a good idea)
% let's generate a frequency vector that has more components than the
% experimental ones

f_toplot = [0:0.1:7.0];
r = f_toplot/fn;
mag_init = K./sqrt((1-r.^2).^2+(2*zeta*r).^2);
```

```
plot(freq,mag,'o-',f_toplot,mag_init)
legend('experiment','theory - initial guess')

% not let's use fminsearch to minimize the difference between the
% experiment and the theoretical equation

x0 = [zeta fn K];    % initial guess of values

% the next lines set up the inputs for fminsearch
options=optimset(@fminsearch)
options=optimset(options,'Display','iter');

% run fminsearch to minimize a cost function J.  The function is defined
% by the m-file "lab2.m" and the outputs are given in the variable coeff.
coeff=fminsearch(@lab3,x0,options)

zeta = coeff(1);
fn = coeff(2);
K = coeff(3);

% now let's plot our final curve
figure
r = f_toplot/fn;
mag_best = K./sqrt((1-r.^2).^2+(2*zeta*r).^2);


plot(freq,mag,'o-',f_toplot,mag_best)
legend('experiment','theory - best fit')
```

File 2: A Matlab function that fminsearch uses to calculate the function it is minimizing.

```
function J = lab3(x)

load freq_resp_data     % load the data mag and freq (in Hz)

zeta = x(1);
fn = x(2);
K = x(3);

r = freq/fn;

% calculate the magnitude for the model
mag_theory = K./sqrt((1-r.^2).^2+(2*zeta*r).^2);

% mag_theory_db = 20*log10(mag_theory);  % If using dB
% mag_db = 20*log10(mag);                % if using dB
 % J = norm(mag_db-mag_theory_db);   % if comparing mag in dB

 J = norm(mag-mag_theory);         % if comparing mag not in dB
```

Download the set of data from the lab portion the course website:
http://fafnir.rose-hulman.edu/~cornwell/courses/em406/em406_labs.htm

Implement the m-files shown above and apply them to the data given. At the beginning of class you will need to run the m-file and show me the resulting figures.