Matlab Assignment:
General Policy
• Though the students are allowed to discuss with each other, each student should work individually and independently on Matlab implementation and report writing.
• A brief report is required, with free form. Contents to be included in the report: results (e.g. figures) and brief discussions of results, and also the codes at the end.
• If a student has a very special situation requiring an unavoidable late submission, she/he should inform the instructor before the due day as early as possible.

Problem 1: FIR digital filter design. (You can use 'fir1' command.)

1 Design an FIR linear phase, digital filter approximating the ideal frequency response

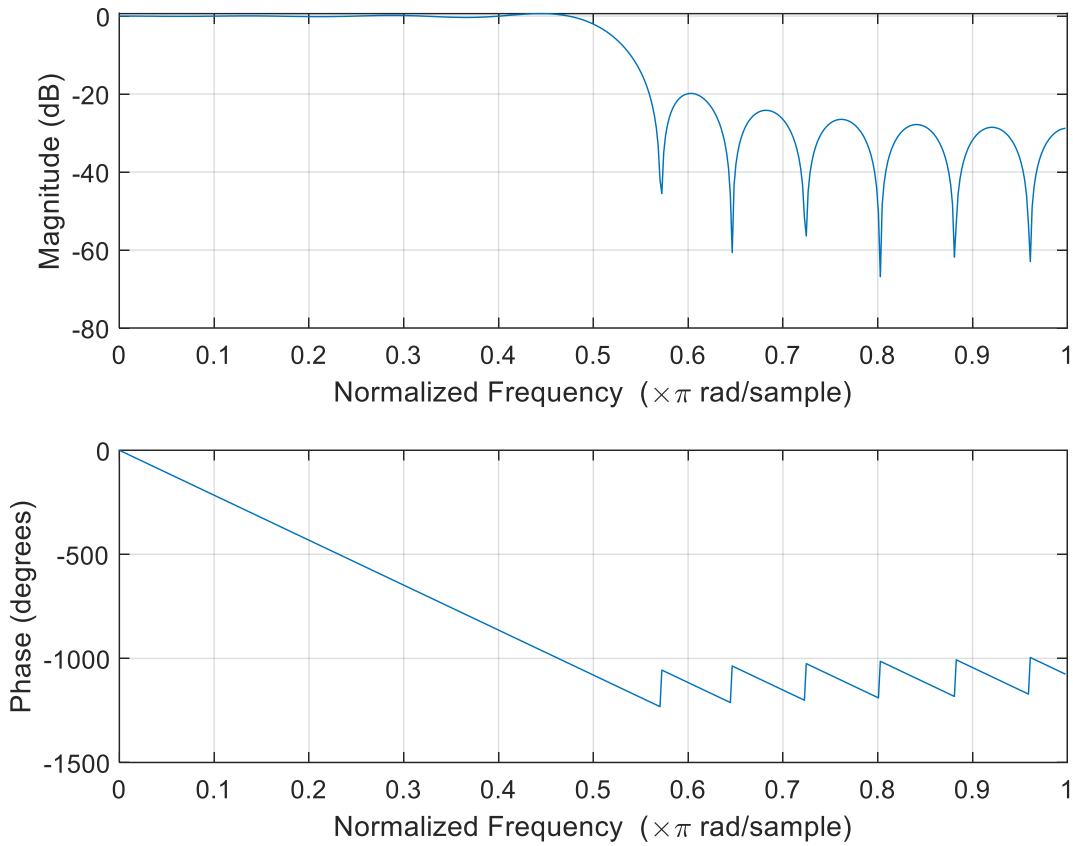
$$H_d(\omega) = \begin{cases} 1, & \text{for } |\omega| \le \dfrac{\pi}{6} \\ 0, & \text{for } \dfrac{\pi}{6} < |\omega| \le \pi \end{cases}$$

(a) Determine the coefficients of a 25-tap filter based on the window method with a rectangular window.
(b) Determine and plot the magnitude and phase response of the filter.
(c) Repeat parts (a) and (b) using the Hamming window.
(d) Repeat parts (a) and (b) using a Bartlett window.

a) h(n) =

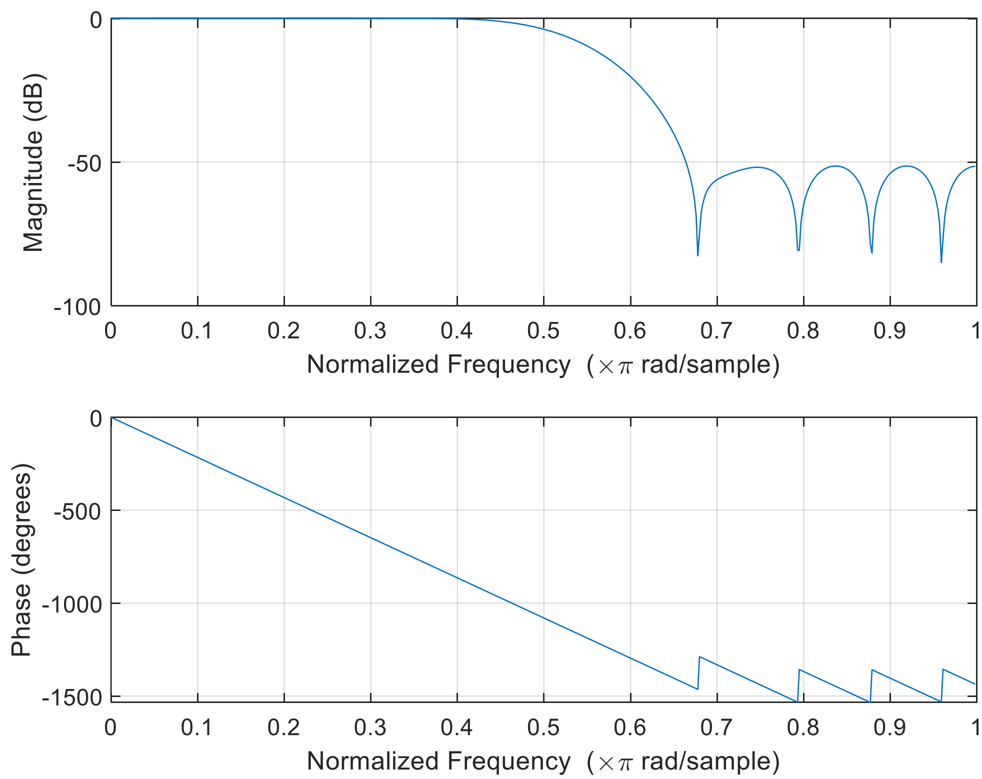
n	h(n)	12	0.521712310915330
0	0.0205324282502707	13	0.316291824121900
1	-0.0197648351352712	14	-0.0234276859280113
2	-0.0214181617586661	15	-0.103116894665481
3	0.0276824426998558	16	0.0231706213464450
4	0.0221592252488131	17	0.0591241459224475
5	-0.0393433242650942	18	-0.0227459412948728
6	-0.0227459412948728	19	-0.0393433242650942
7	0.0591241459224475	20	0.0221592252488131
8	0.0231706213464450	21	0.0276824426998558
9	-0.103116894665481	22	-0.0214181617586661
10	-0.0234276859280113	23	-0.0197648351352712
11	0.316291824121900	24	0.0205324282502707

b)


Magnitude (dB)
0
-20
-40
-60
-80
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Frequency (×π rad/sample)
Phase (degrees)
0
-500
-1000
-1500
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Frequency (×π rad/sample)

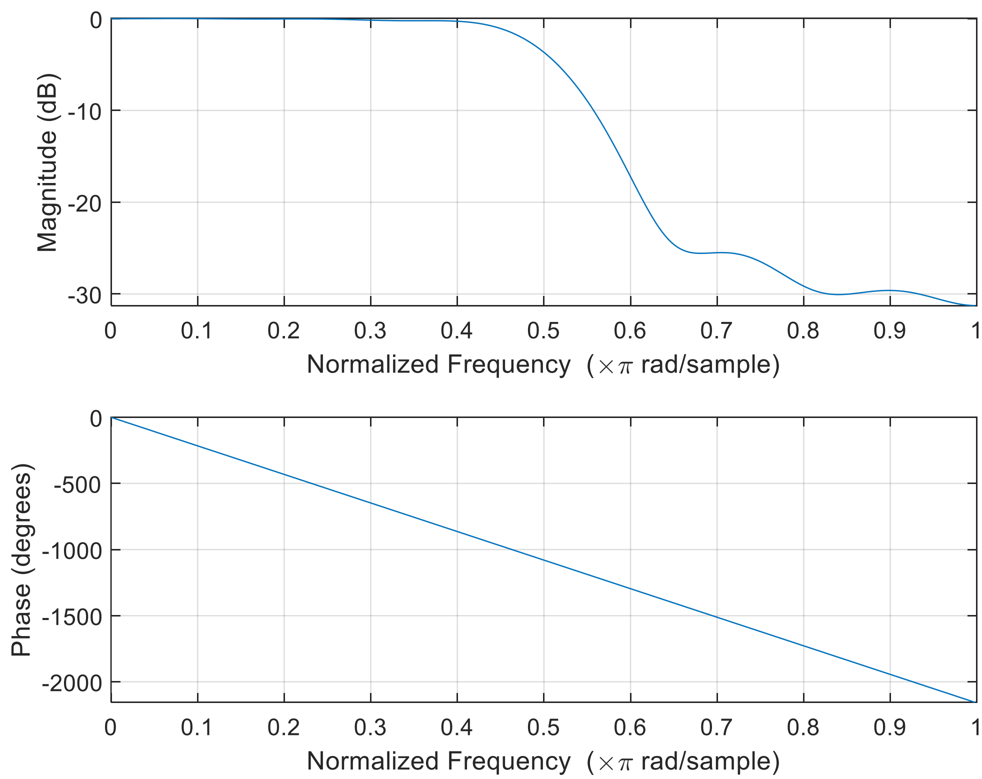
c)

n	h(n)	12	-0.0220510047293028
0	0.00164760990838365	13	0.312284884706658
1	-0.00189675730868747	14	0.523305355260709
2	-0.00304268066231678	15	0.312284884706658
3	0.00596242609641815	16	-0.0220510047293028
4	0.00689033536211566	17	-0.0894963089899393
5	-0.0166118761748928	18	0.0178958569423255
6	-0.0123203137555855	19	0.0390851509744693
7	0.0390851509744693	20	-0.0123203137555855
8	0.0178958569423255	21	-0.0166118761748928
9	-0.0894963089899393	22	0.00689033536211566
10	0.00164760990838365	23	0.00596242609641815
11	-0.00189675730868747	24	-0.00304268066231678



d)

n	h(n)	12	-0.0201189969220820
0	0	13	0.298784168487494
1	-0.00169734500656137	14	0.537637139738222
2	-0.00367865551743664	15	0.298784168487494
3	0.00713185648619527	16	-0.0201189969220820
4	0.00761187231118796	17	-0.0796983382604626
5	-0.0168934358738242	18	0.0159185900300799
6	-0.0117201209963527	19	0.0355418353926514
7	0.0355418353926514	20	-0.0117201209963527
8	0.0159185900300799	21	-0.0168934358738242
9	-0.0796983382604626	22	0.00761187231118796
10	0	23	0.00713185648619527
11	-0.00169734500656137	24	-0.00367865551743664

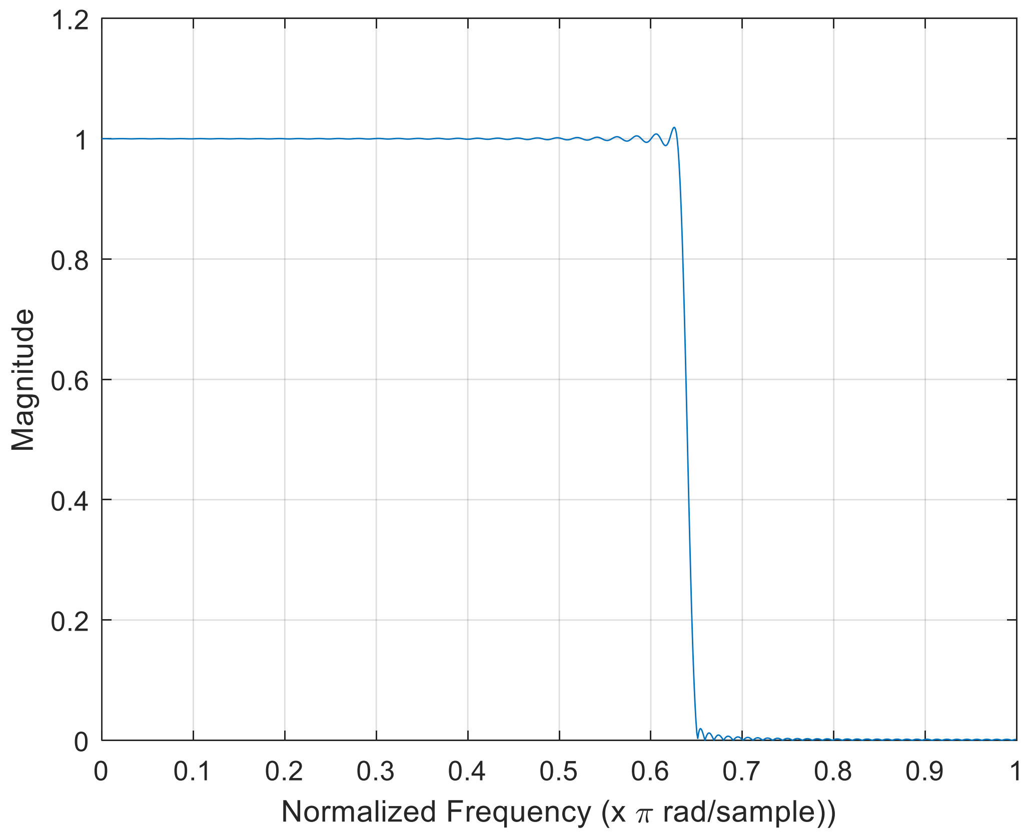


Problem 2: FIR filter design using windows

7.16. We wish to design an FIR lowpass filter satisfying the specifications

$$0.98 < H(e^{j\omega}) < 1.02, \qquad 0 \le |\omega| \le 0.63\pi,$$
$$-0.15 < H(e^{j\omega}) < 0.15, \qquad 0.65\pi \le |\omega| \le \pi,$$

by applying a Kaiser window to the impulse response $h_d[n]$ for the ideal discrete-time lowpass filter with cutoff $\omega_c = 0.64\pi$. Find the values of β and M required to satisfy this specification.



$\beta = 2.652339138368929$

M = 182

Problem 3: Integer filters

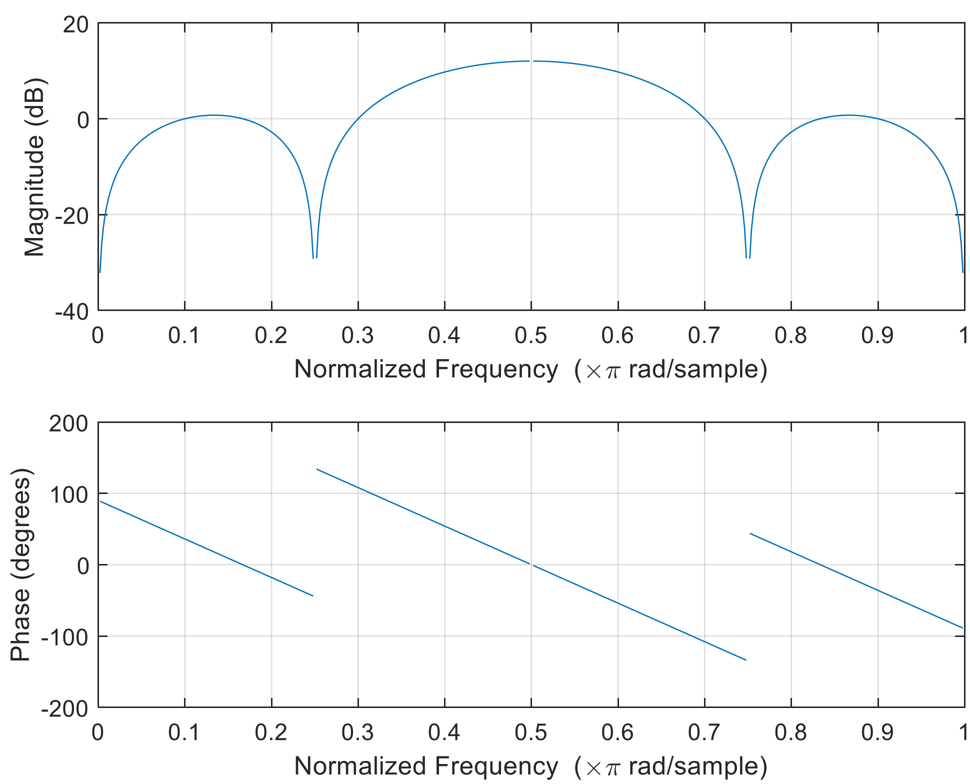
7.14 For a filter with the following transfer function, what is the (a) amplitude response, (b) phase response, (c) difference equation?

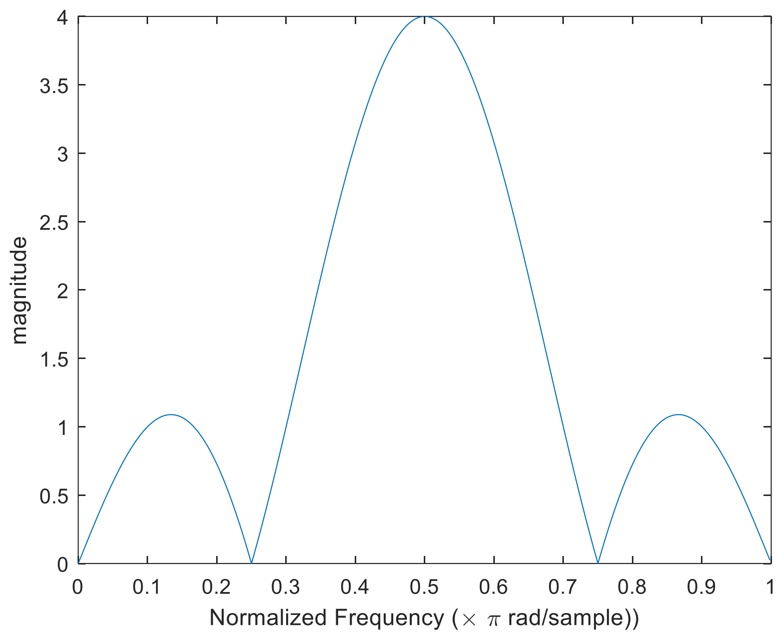
$$H(z) = \frac{1 - z^{-8}}{1 + z^{-2}}$$

7.15 A digital filter has the following transfer function. (a) What traditional filter type best describes this filter? (b) Draw its pole-zero plot. (c) Calculate its amplitude response. (d) What is its difference equation?

$$H(z) = \frac{(1 - z^{-8})^2}{(1 + z^{-2})^2}$$

7.14 a)b)

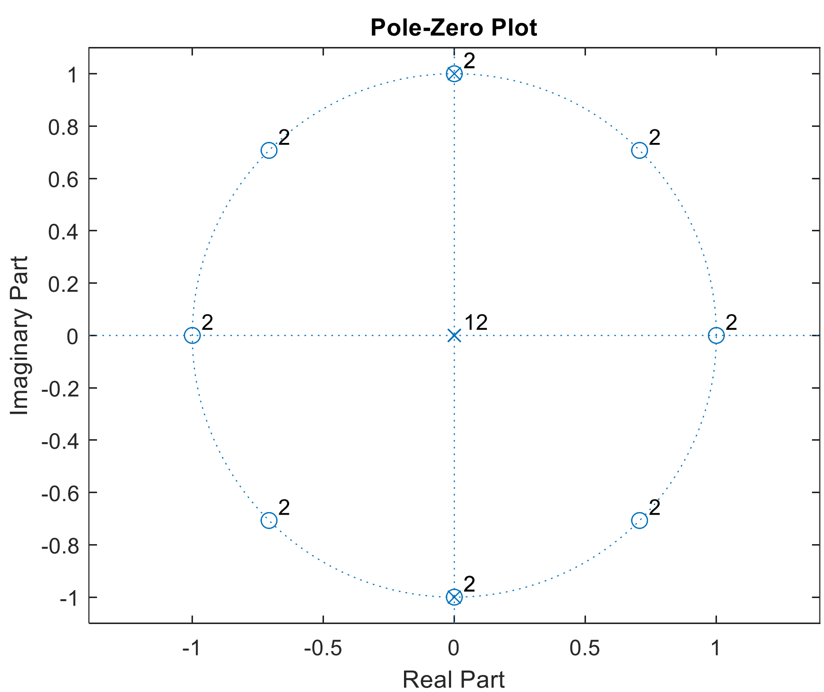




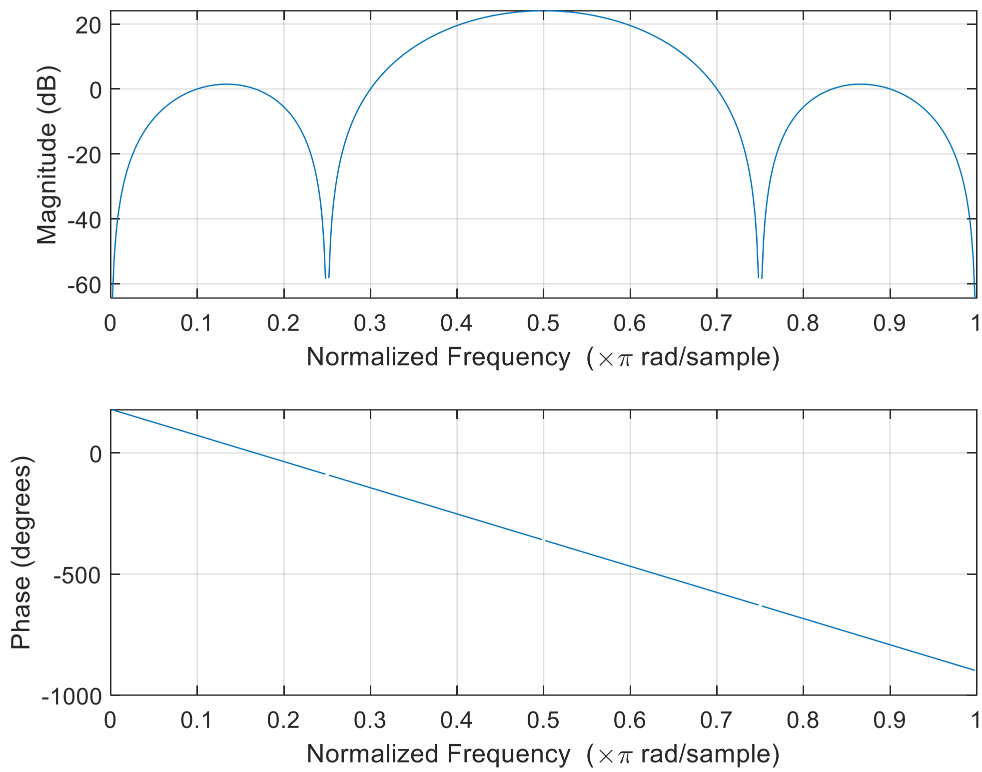
c) y(n) = x(n) - x(n-8) - y(n-2)

7.15 a) bandpass filter

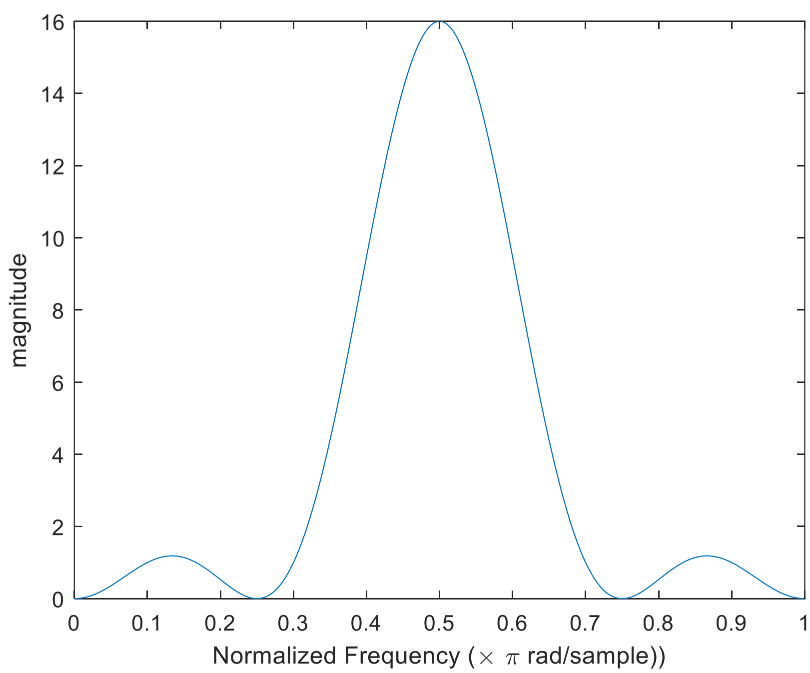
b)



c)



Magnitude (dB)
20
0
-20
-40
-60
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)
Phase (degrees)
0
-500
-1000
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)



magnitude
16
14
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (× π rad/sample))

d) y(n) = x(n) - 2x(n-8)+ x(n-16)- y(n-2) - y(n-4)

Problem 4: AR processes

The power spectrum of an EMG signal typically spans in the range of 20-400Hz. When the muscle fatigues, the spectrum of its EMG signal increases at low frequencies (e.g. below 100 Hz) and decreases at high frequencies. Some researches proposed that they could determine muscle fatigue by calculating and AR(2) model of an EMG signal and looking for changes in the parameters of this model. In the following table are the calculated auto-correlation values for the diaphragm EMG from one subject before and during fatigue of the diaphragm muscle.

Lag	0	1	2	3	4	5	6	7
Rest	1	0.83	0.47	0.08	-0.22	-0.37	-0.39	-0.26
Fatigue	1	0.9	0.66	0.36	0.07	-0.17	-0.32	-0.37

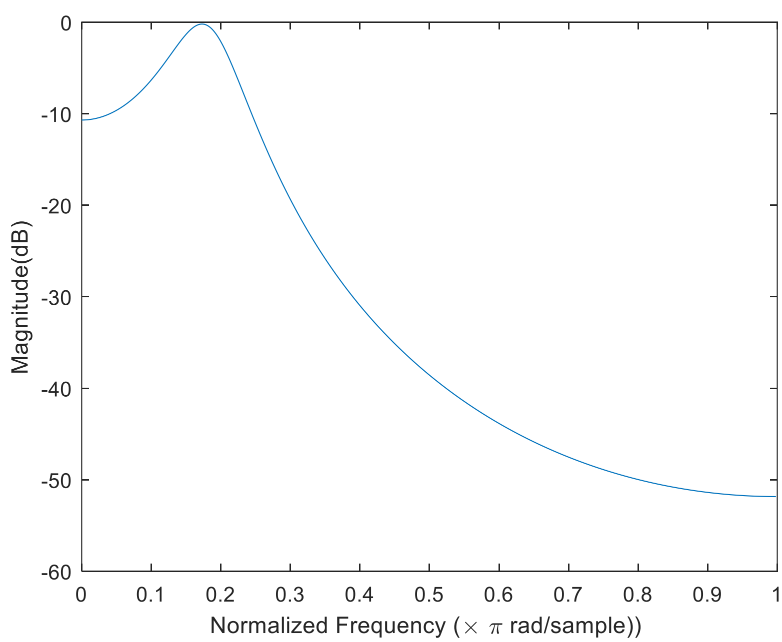
Auto-correlation values.

(a) Calculate the AR(4) or AR(3) models of both conditions, then compute the power spectrums correspondingly. Comment on your results.

Rest AR(3) model: $\sigma^2 = 0.157072811361683$

a(1)	-1.41145172512585
a(2)	0.698481561822126
a(3)	0.00364261449678638

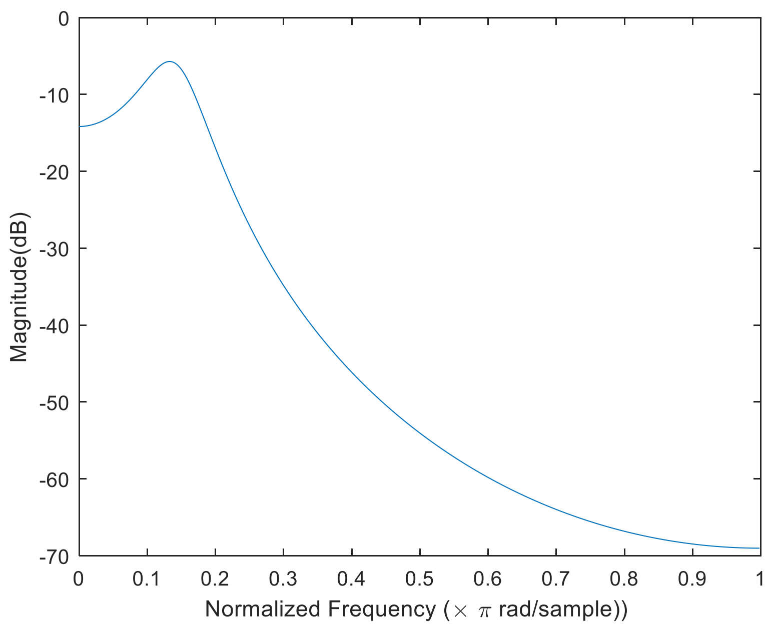
$$\hat{S}_{xx}(\omega) = \frac{0.157}{|1 - 1.41e^{-j\omega k} + 0.698e^{-2j\omega k} + 0.0036e^{-3j\omega k}|^2}$$



Fatigue AR(3) model: $\sigma^2 = 0.070776470588235$

a(1)	-1.69411764705883
a(2)	0.960000000000004
a(3)	-0.105882352941180

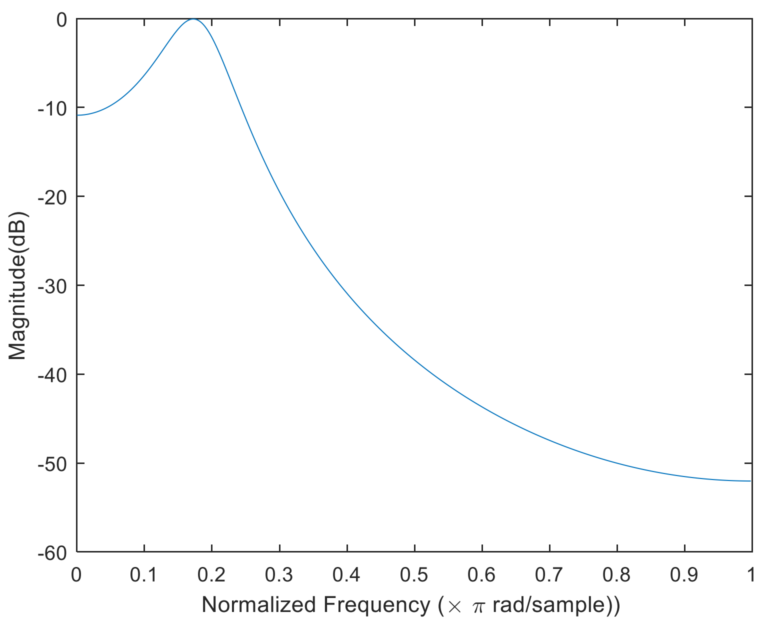
$$\hat{S}_{xx}(\omega) = \frac{0.0708}{|1 - 1.69e^{-j\omega k} + 0.960e^{-2j\omega k} - 0.105e^{-3j\omega k}|^2}$$



Rest AR(4) model: $\sigma^2 = 0.157056381847745$

a(1)	-1.41141447094138
a(2)	0.705625156341200
a(3)	-0.0107927541065640
a(4)	0.0102273201033936

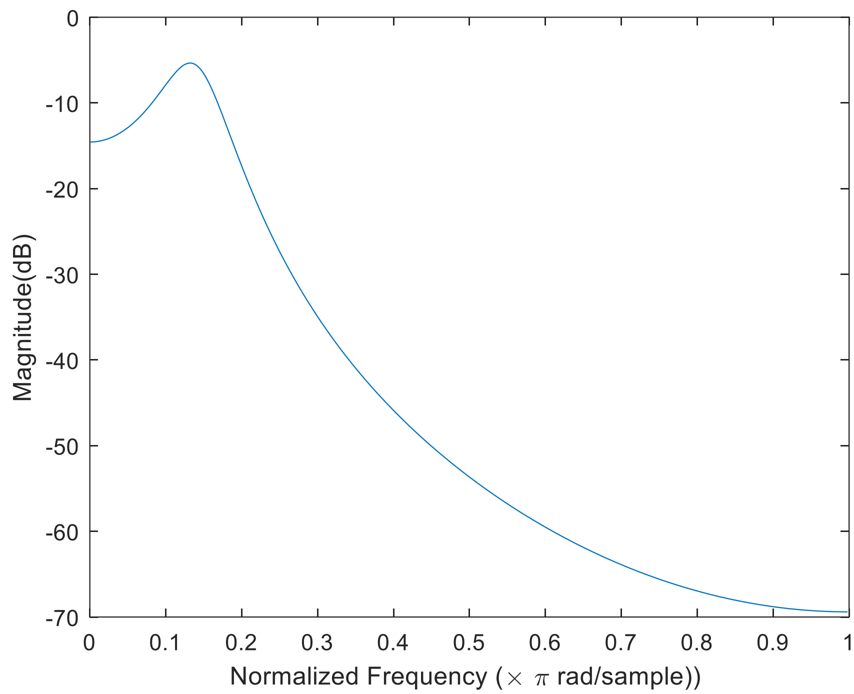
$$\hat{S}_{xx}(\omega) = \frac{0.157}{|1 - 1.411 + 0.706e^{-2j\omega k} - 0.010e^{-3j\omega k} + 0.010e^{-4j\omega k}|^2}$$



Fatigue AR(4) model: $\sigma^2 = 0.070741356382985$

a(1)	-1.69647606382979
a(2)	0.981382978723411
a(3)	-0.143617021276594
a(4)	0.0222739361702135

$$\hat{S}_{xx}(\omega) = \frac{0.0708}{|1 - 1.696e^{-j\omega k} + 0.981e^{-2j\omega k} - 0.147e^{-3j\omega k} + 0.022e^{-4j\omega k}|^2}$$



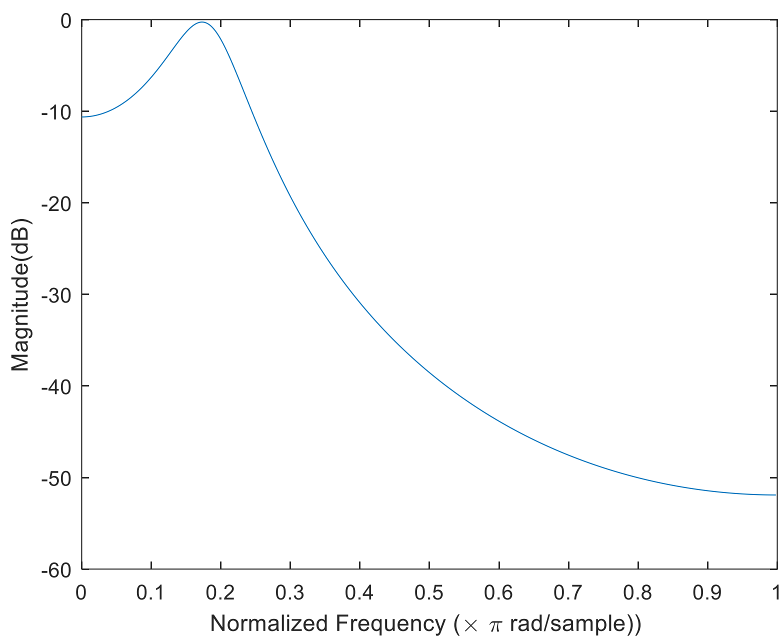
From these results we see that the magnitude of the power spectrum at rest is higher at Rest than it is when fatigued and between the AR3 and AR4 models the 4^{th} coefficient is very small in both cases and the first 3 coefficients are very similar causing the power spectrum to be very similar

(b) Calculate the AR(2) parameters for both condition. Do the changes in AR(2) parameters qualitatively reflect the expected changes in the power spectrum?

Rest AR(2) model: $\sigma^2 = 0.157074895531983$

a(1)	-1.41401478624237
a(2)	0.703632272581164

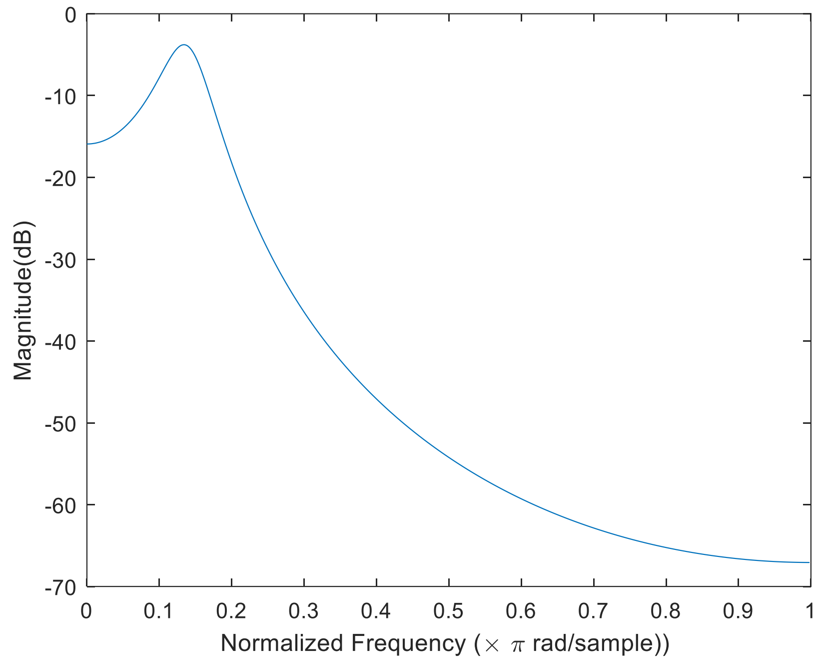
$$\hat{S}_{xx}(\omega) = \frac{0.0708}{|1 - 1.414e^{-j\omega k} + 0.704e^{-2j\omega k}|^2}$$



Fatigue AR(2) model: $\sigma^2 = 0.070741356382985$

a(1)	-1.61052631578947
a(2)	0.789473684210527

$$\hat{S}_{xx}(\omega) = \frac{0.0708}{|1 - 1.611e^{-j\omega k} + 0.789e^{-2j\omega k}|^2}$$



In the AR(2) models the changes to the 2nd coefficient is more dramatic. I don't see any dramatic changes in the power spectrum so I will say that the observed changes weren't dramatic enough to qualitatively affect the power spectrum.

Matlab Code:

Assignment3_q1.m

```
clear; close all;
% Assignment 3 q1
% Andrew Munro-West 18363572
%
% Problem 1: Design an FIR linear phase, digital filter aproximating the
% ideal frequency response H_d(w) = 1 for |w| <= pi/6 and 0 elsewhere
wm= 1/6;
b = fir1(24,wm,'low',rectwin(25));

% (a) Determine the coefficients of a 25-tap filter based on the window
% method with a rectangular window
h_a = impz(b);

% (b) Determine and plot the magnitude and phase response of the filter
freqz(b,1)
% (c) repeat parts (a) and (b) using the Hamming window

figure
b = fir1(24,wm,'low',hamming(25));
h_c = impz(b);
freqz(b,1)
% (d) repeat parts (a) and (b) using the Bartlett window

figure
b = fir1(24,wm,'low',bartlett(25));
h_d = impz(b);
freqz(b,1)
```

Assignment3_q2.m

```
clear; close all;
% Assignment 3 q2
% Andrew Munro-West 18363572
%
% Problem 2: Design an FIR low pass filter with specifications

% L=30;
% wm= 0.63;
% b = fir1(30,wm,'low');
% freqz(b,1)

fcuts = [0.63 0.65];
mags = [1 0];
devs = [0.02 0.15];
[n,Wn,beta,ftype] = kaiserord(fcuts,mags,devs);
hh = fir1(n,Wn,ftype,kaiser(n+1,beta),'noscale');

[H,f] = freqz(hh,1,1024);
plot(f/pi,abs(H))
xlabel('Normalized Frequency (x \pi rad/sample))')
```

```
ylabel('Magnitude')
grid
```

Assignment3_q3.m

```
clear; close all;
% Assignment 3 q3
% Andrew Munro-West 18363572
%
% Problem 3: Integer filters
%

% ts = -1;
% z = tf('z',ts);
% sys = (1-(z^-8))/(1+(z^-2))

% part 1

b = [1 0 0 0 0 0 0 0 -1];
a = [1 0 1];


[h,f] = freqz(b,a)
freqz(b,a)
figure
plot(f/pi,abs(h))
ylabel('magnitude')
xlabel('Normalized Frequency (\times \pi rad/sample))')

% part 2

b1 = [1 0 0 0 0 0 0 0 -2 0 0 0 0 0 0 0 1];
a1 = [1 0 2 0 1];
figure

zplane(b1,a1)
title('Pole-Zero Plot')


figure
[h,f] = freqz(b1,a1)
freqz(b1,a1)
figure
plot(f/pi,abs(h))
ylabel('magnitude')
xlabel('Normalized Frequency (\times \pi rad/sample))')
```

Assignment3_q4.m

```
clear; close all;
% Assignment 3 q3
% Andrew Munro-West 18363572
%
% Problem 3: Integer filters
%

Rest = [1 0.83 0.47 0.08 -0.22 -0.37 -0.39 -0.26];
Fatigue = [1 0.9 0.66 0.36 0.07 -0.17 -0.32 -0.37];

Rest = toeplitz(Rest);
Fatigue = toeplitz(Fatigue);

%AR(3) models
%solve for coefficients
a_Rest3 = inv(Rest(2:4,2:4))*-Rest(2:4,1)
omega_Rest3 = Rest(1,1:4)*[1;a_Rest3]
[H,F] = freqz(omega_Rest3,[1;a_Rest3]); % frequency domain magnitude response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')

figure
a_Fatigue3 = inv(Fatigue(2:4,2:4))*-Fatigue(2:4,1)
omega_Fatigue3 = Fatigue(1,1:4)*[1;a_Fatigue3]
[H,F] = freqz(omega_Fatigue3,[1;a_Fatigue3]); % frequency domain magnitude
response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')
%
% %AR(4) models
figure
a_Rest4 = inv(Rest(2:5,2:5))*-Rest(2:5,1)
omega_Rest4 = Rest(1,1:5)*[1;a_Rest4]
[H,F] = freqz(omega_Rest4,[1;a_Rest4]); % frequency domain magnitude response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')

figure
a_Fatigue4 = inv(Fatigue(2:5,2:5))*-Fatigue(2:5,1)
omega_Fatigue4 = Fatigue(1,1:5)*[1;a_Fatigue4]
[H,F] = freqz(omega_Fatigue4,[1;a_Fatigue4]); % frequency domain magnitude
response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')
```

```
%b) calculate the AR(2) parameters do the changes qualitatively reflect the
%expected changes in the power spectrum?

%AR(3) models
%solve for coefficients
figure
a_Rest2 = inv(Rest(2:3,2:3))*-Rest(2:3,1)
omega_Rest2 = Rest(1,1:3)*[1;a_Rest2]
[H,F] = freqz(omega_Rest2,[1;a_Rest2]); % frequency domain magnitude response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')%AR(2) models
%solve for coefficients

figure
a_Fatigue2 = inv(Fatigue(2:3,2:3))*-Fatigue(2:3,1)
omega_Fatigue2 = Fatigue(1,1:3)*[1;a_Fatigue2]
[H,F] = freqz(omega_Fatigue2,[1;a_Fatigue2]); % frequency domain magnitude
response
plot(F/pi,20*log10((abs(H).^2)))  % plot w=0 to 2=pi of omega^2*|H(w)|^2
xlabel('Normalized Frequency (\times \pi rad/sample)) ')
ylabel('Magnitude(dB)')
```