ECE 421 Project 2

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Ideal Impulse Response:

```
% 10.1 Ideal Impulse Response
M = 25;
n = [0:1:M-1];
hd1_ideal = ideal_lp(pi/6,M);
figure(1);
stem(hd1_ideal);
xlabel('n'); ylabel('h(n)');
title('Ideal Impulse Response of 10.1')
```

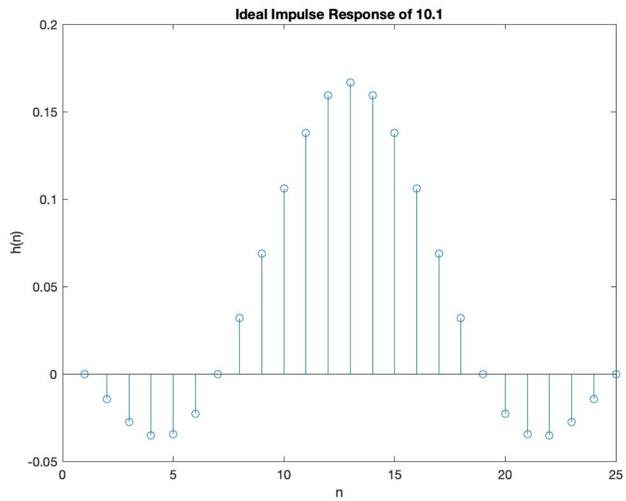

Figure 1

```
% 10.2 Ideal Impulse Response
wc1=pi/6;
wc2=pi/3;
wc3=pi;
hd2_ideal = ideal_lp(wc1,M)+ideal_lp(wc3,M)-ideal_lp(wc2,M);
figure(2);
stem(hd2_ideal);
xlabel('n'); ylabel('h(n)');
title('Ideal Impulse Response of 10.2')
```

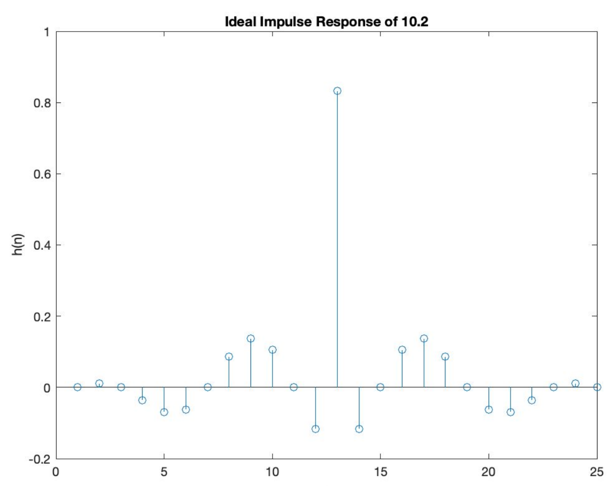

Figure 2

Actual Impulse Response:

```
%% Actual Impulse Response for 10.1 - Rectangular window
hd1_mag_rect = hd1_ideal .* rectwin(M)';
figure(2)
stem(n,hd1_mag_rect);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.1 Rectangular')
```

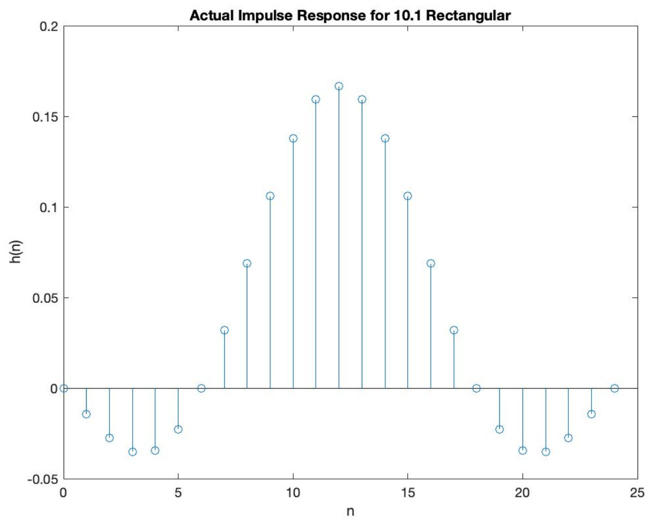

Figure 3

```
%% Actual Impulse Response for 10.1 - Hamming window
hd1_mag_hamm = hd1_ideal .* hamming(M)';
figure(2)
stem(n,hd1_mag_hamm);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.1 Hamming')
```

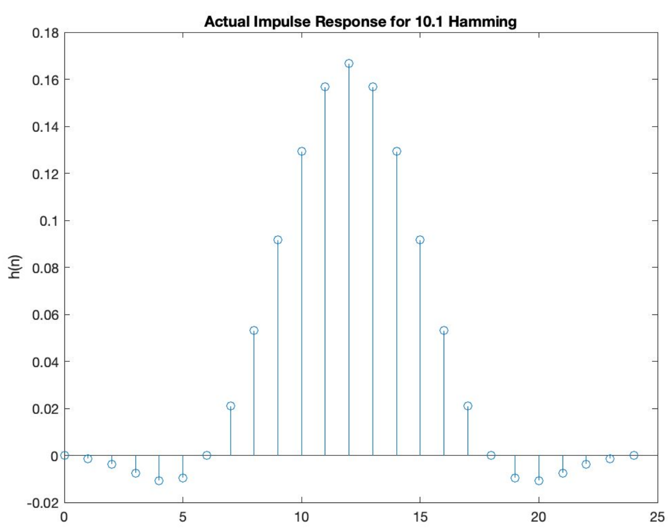

Figure 4

```
%% Actual Impulse Response for 10.1 - Bartlett window
hd1_mag_bart = hd1_ideal .* bartlett(M)';
figure(2)
stem(n,hd1_mag_bart);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.1 Bartlett')
```

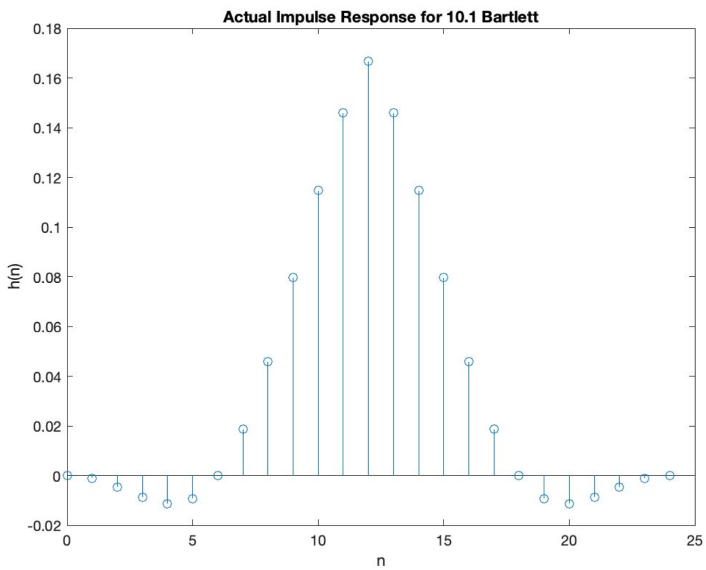

Figure 5

```
%% Actual Impulse Response for 10.1 - Hanning window
hd1_mag_hann = hd1_ideal .* hann(M)';
figure(2)
stem(n,hd1_mag_hann);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.1 Hanning')
```

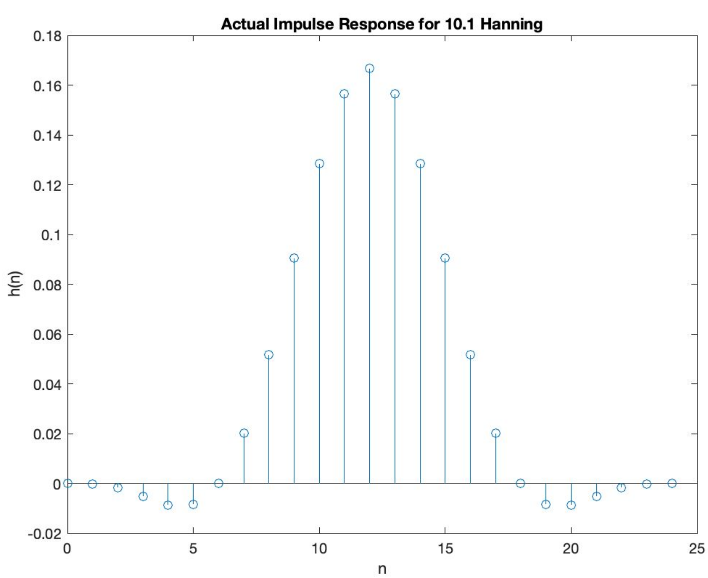

Figure 6

```
%% Actual Impulse Response for 10.1 - Blackman window
hd1_mag_black = hd1_ideal .* blackman(M)';
figure(2)
stem(n,hd1_mag_black);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.1 Blackman')
```

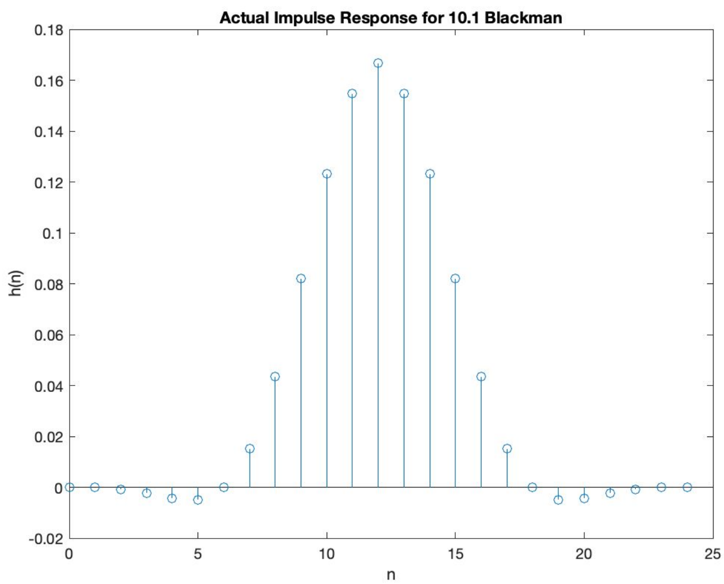

Figure 7

```
%% Actual Impulse Response for 10.2 - Rectangular window
hd2_mag_rect = hd2_ideal .* rectwin(M)';
figure(3)
stem(hd2_mag_rect);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.2 Rectangular')
```

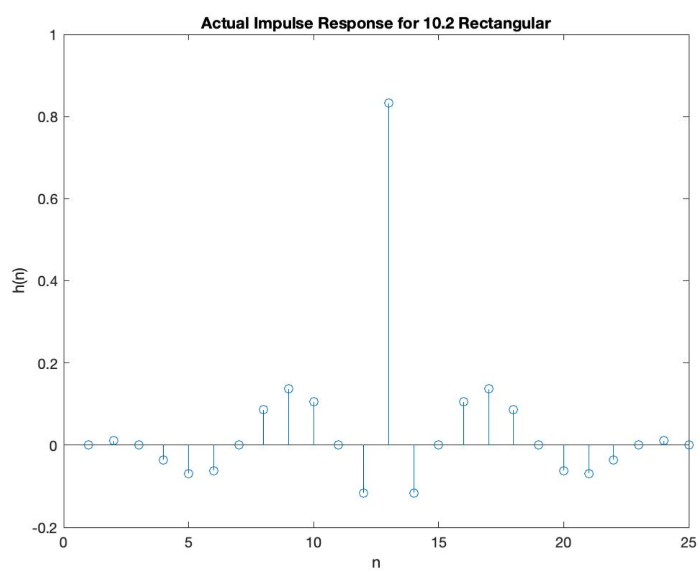

Figure 8

```
%% Actual Impulse Response for 10.2 - Hamming window
hd2_mag_hamm = hd2_ideal .* hamming(M)';
figure(3)
stem(hd2_mag_hamm);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.2 Hamming')
```

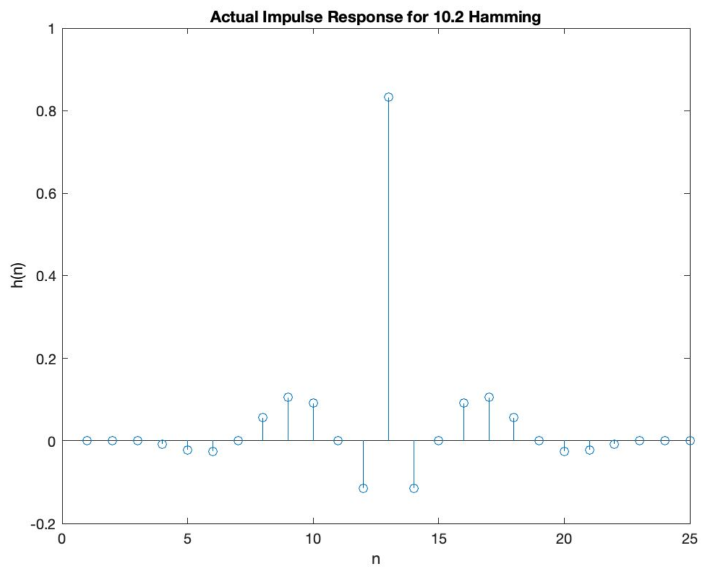

Figure 9

```
%% Actual Impulse Response for 10.2 - Bartlett window
hd2_mag_bart = hd2_ideal .* bartlett(M)';
figure(3)
stem(hd2_mag_bart);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.2 Bartlett')
```

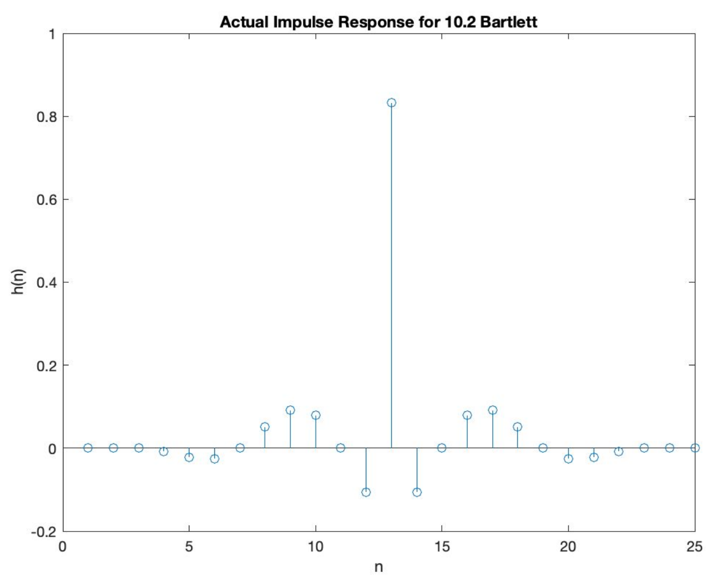

Figure 10

```
%% Actual Impulse Response for 10.2 - Hanning window
hd2_mag_hann = hd2_ideal .* hann(M)';
figure(3)
stem(hd2_mag_hann);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.2 Hanning')
```

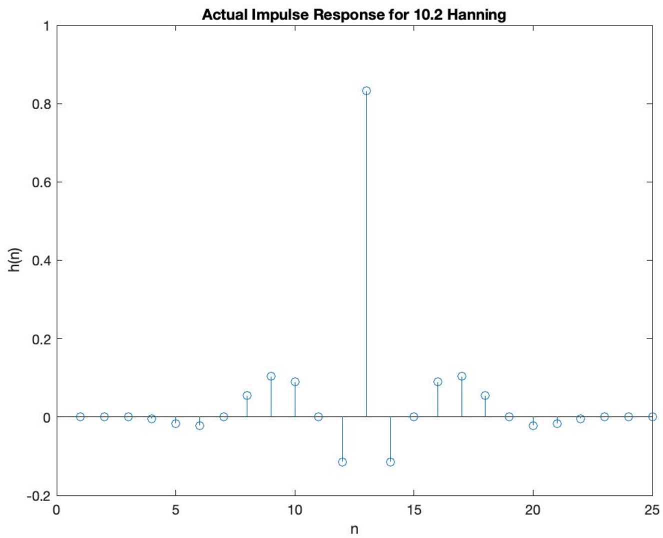

Figure 11

```
%% Actual Impulse Response for 10.2 - Blackman window
hd2_mag_black = hd2_ideal .* blackman(M)';
figure(3)
stem(hd2_mag_black);
xlabel('n'); ylabel('h(n)');
title('Actual Impulse Response for 10.2 Blackman')
```

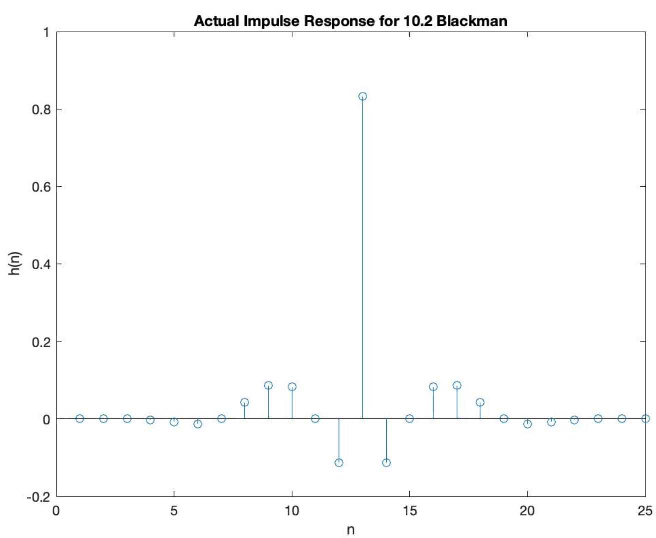

Figure 12

Magnitude of Frequency Response:

```
%% Magnitude of Freq Response for 10.1 - Rectangular window
hd1_mag_rect = hd1_ideal .* rectwin(M)';
figure(2)
[db,mag,pha,grd,w] = freqz_m(hd1_mag_rect,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.1 Rectangular')
```

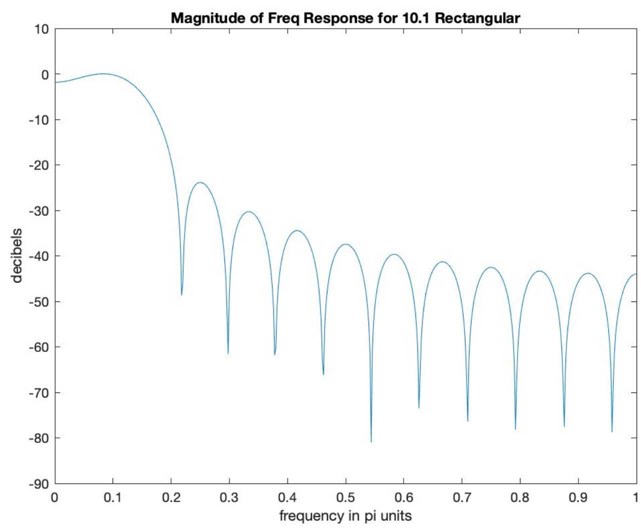

Figure 13

```
%% Magnitude of Freq Response for 10.1 - Hamming window
hd1_mag_hamm = hd1_ideal .* hamming(M)';
figure(2)
[db,mag,pha,grd,w] = freqz_m(hd1_mag_hamm,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.1 Hamming')
```

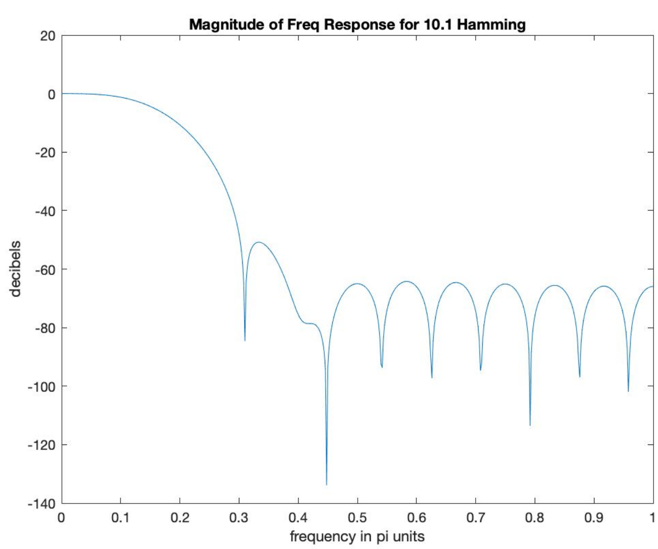

Figure 14

```
%% Magnitude of Freq Response for 10.1 - Bartlett window
hd1_mag_bart = hd1_ideal .* bartlett(M)';
figure(2)
[db,mag,pha,grd,w] = freqz_m(hd1_mag_bart,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.1 Bartlett')
```

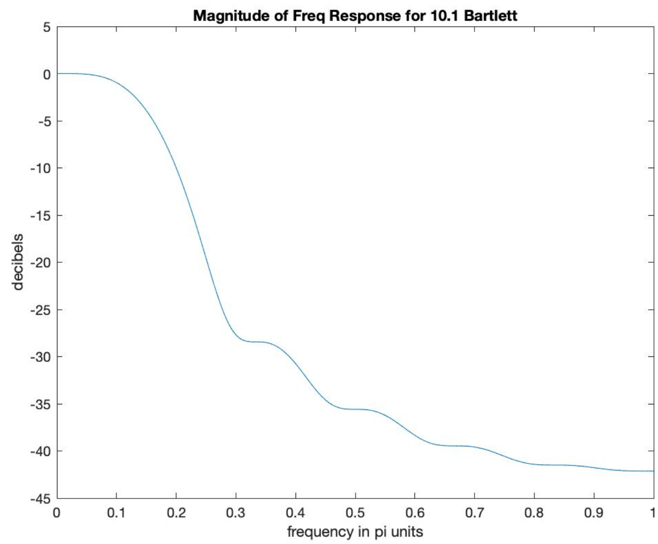

Figure 15

```
%% Magnitude of Freq Response for 10.1 - Hanning window
hd1_mag_hann = hd1_ideal .* hann(M)';
figure(2)
[db,mag,pha,grd,w] = freqz_m(hd1_mag_hann,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.1 Hanning')
```

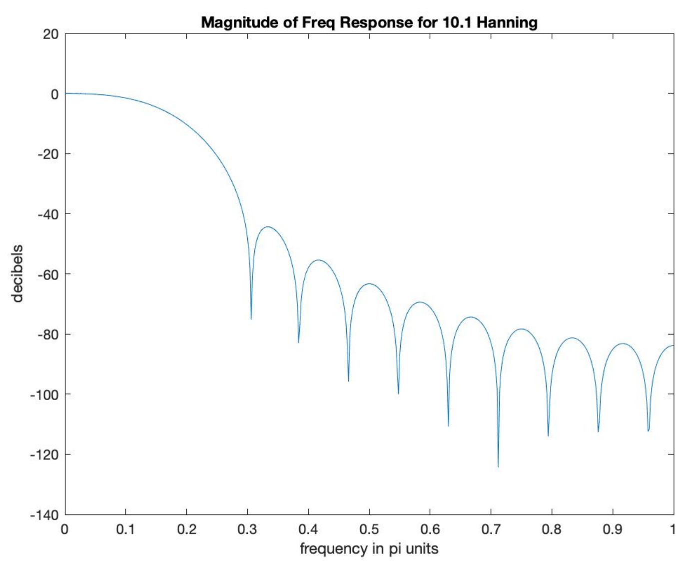

Figure 16

```
%% Magnitude of Freq Response for 10.1 - Blackman window
hd1_mag_black = hd1_ideal .* blackman(M)';
figure(2)
[db,mag,pha,grd,w] = freqz_m(hd1_mag_black,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.1 Blackman')
```

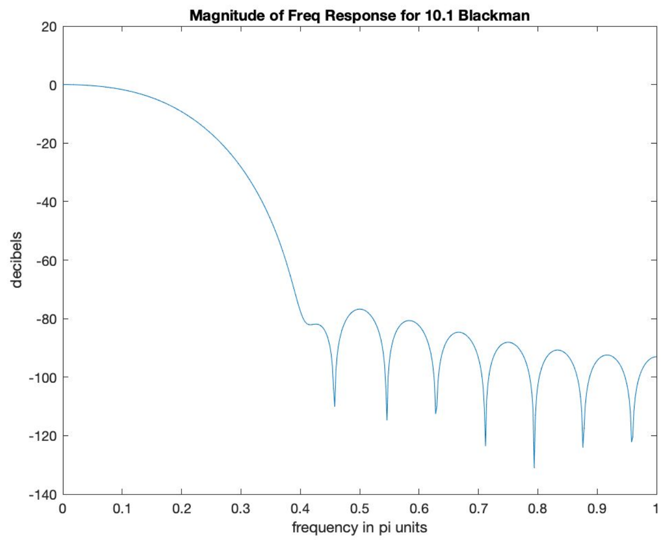

Figure 17

```
%% Magnitude of Freq Response for 10.2 - Rectangular window
hd2_mag_rect = hd2_ideal .* rectwin(M)';
figure(3)
[db,mag,pha,grd,w] = freqz_m(hd2_mag_rect,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.2 Rectangular')
```

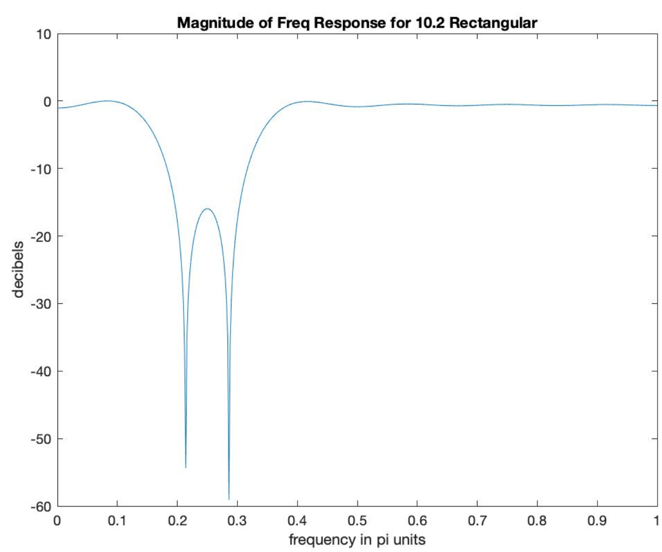

Figure 18

```
%% Magnitude of Freq Response for 10.2 - Hamming window
hd2_mag_hamm = hd2_ideal .* hamming(M)';
figure(3)
[db,mag,pha,grd,w] = freqz_m(hd2_mag_hamm,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.2 Hamming')
```

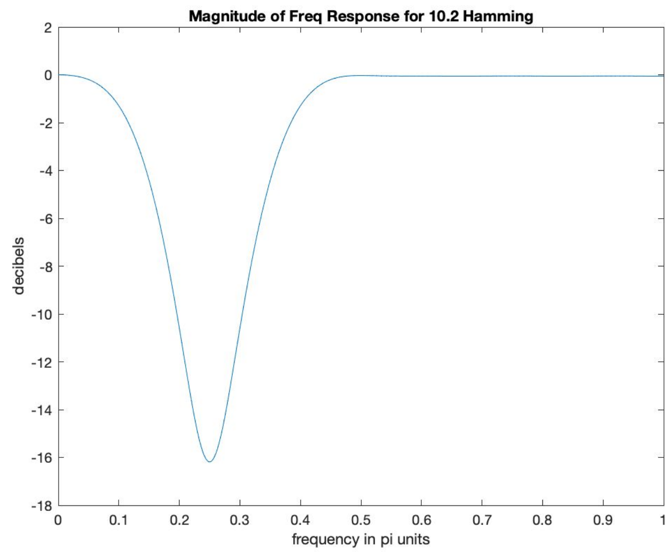

Figure 19

```
%% Magnitude of Freq Response for 10.2 - Bartlett window
hd2_mag_bart = hd2_ideal .* bartlett(M)';
figure(3)
[db,mag,pha,grd,w] = freqz_m(hd2_mag_bart,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.2 Bartlett')
```

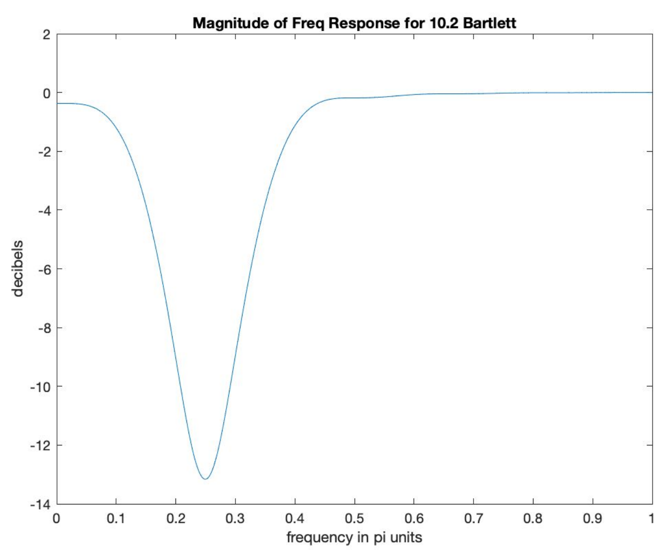

Figure 20

```
%% Magnitude of Freq Response for 10.2 - Hanning window
hd2_mag_hann = hd2_ideal .* hann(M)';
figure(3)
[db,mag,pha,grd,w] = freqz_m(hd2_mag_hann,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.2 Hanning')
```

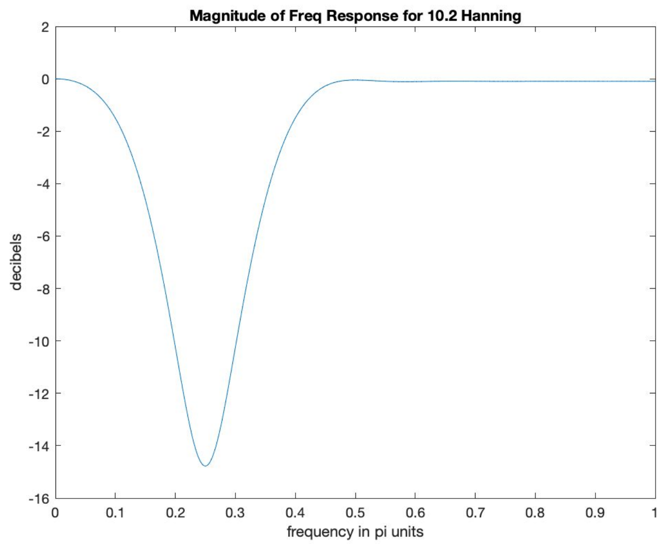

Figure 21

```
%% Magnitude of Freq Response for 10.2 - Blackman window
hd2_mag_black = hd2_ideal .* blackman(M)';
figure(3)
[db,mag,pha,grd,w] = freqz_m(hd2_mag_black,[1]);
plot(w/pi,db);
xlabel('frequency in pi units'); ylabel('decibels');
title('Magnitude of Freq Response for 10.2 Blackman')
```

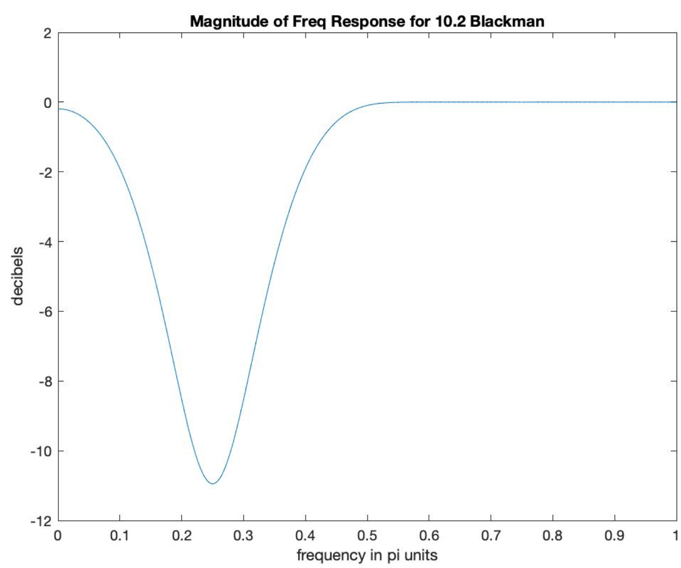

Figure 22

Discussion of Results:

1. From comparing the different FIR filters in Problems 10.1 and 10.3, we can see that the rectangle window magnitude plot (Figure 13) has the smallest main lobe width ranging from 0 pi units to 0.2 pi units. This can also be observed in the magnitude plot of a lowpass FIR filter with rectangle window shown in the textbook as Figure 10.2.8. The filter through the rectangle window also has the smallest transition bandwidth. The smallest side lobes can be seen in the Blackman window magnitude plot (Figure 17).
2. If I had to choose one actual filter that approximates the ideal lowpass frequency response, I would choose the lowpass filter with the Bartlett window. We can observe that the magnitude of this filter (Figure 15) has one of the smaller main lobes as well as a small transition bandwidth. These features indicate that the Bartlett window filter behaves closely to the ideal lowpass filter.
3. We will now discuss the characteristics of the stopband FIR filters from Problems 10.2 and 10.4. The stopband filter with the rectangular window (Figure 18) has a small transition width, but does not offer a smooth stopband attenuation. Smoother stopband attenuation can be seen in the stopband filters with the Bartlett (Figure 20) and Blackman (Figure 22) windows, but these filter windows have a larger transition bandwidth. The Hamming and Hanning windows are more in the middle instead of having one extremely positive feature and one negative feature. The Hamming and Hanning windows have a transition bandwidth considered to be on the smaller side and they also have smoother stopband attenuation than the rectangular window. Now that we have narrowed down to these two filters, we can take a closer look at them to see which one truly provides the best approximation to the ideal stopband frequency response. The Hamming window (Figure 19) has less smooth attenuation and can be seen around and crosses the value of -16 dB. On the other hand, the Hamming window (Figure 21) only reaches about -14 dB, which proves it to be the better choice. As the textbook suggests, a larger M value (in our case 25) shows better results in terms of having characteristics closer to the ideal stopband filter (pg. 664-665). This tells us that if we increase the value of M, we can get better results from our filters.