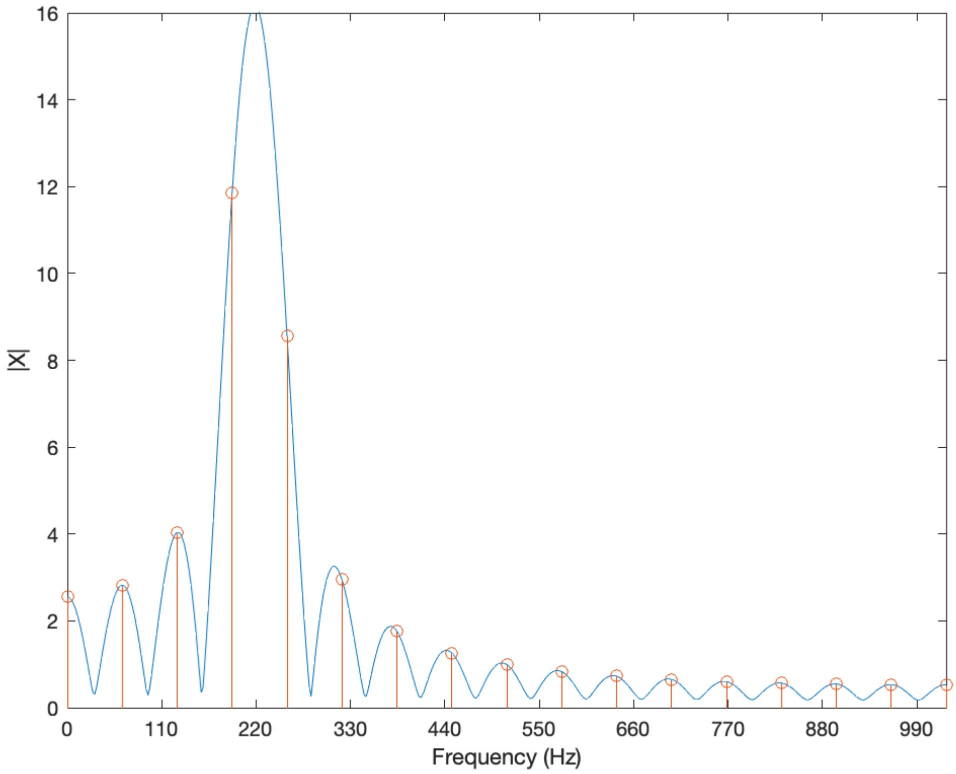
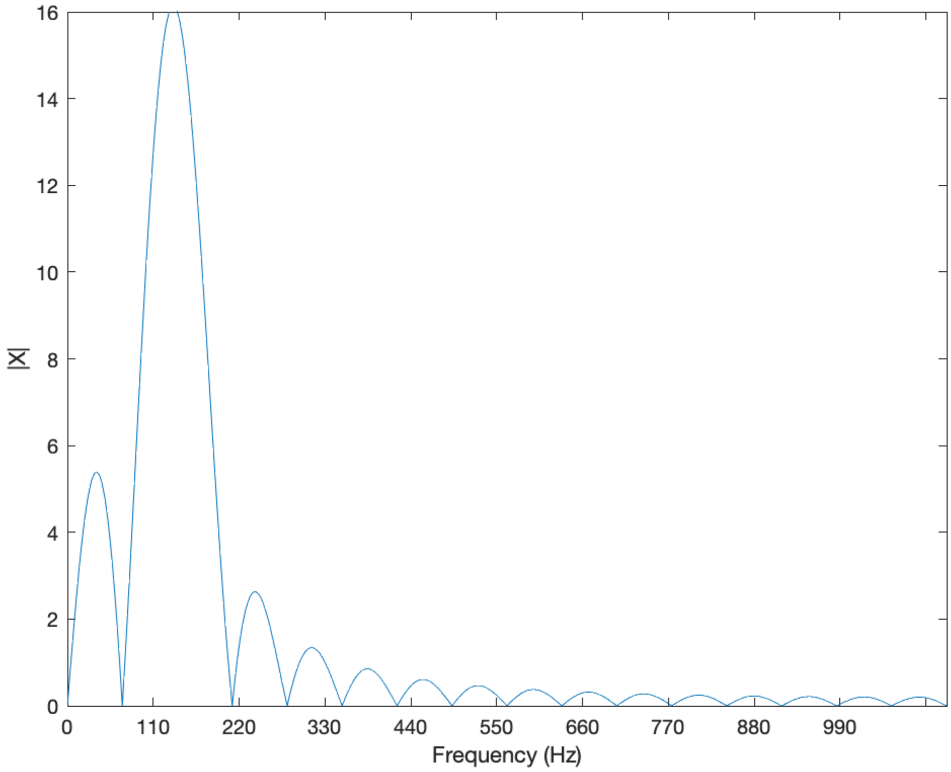
[1-1]

```
n = [0:31];
x = sin(2*pi*220*n/2048);

x_padded = [x zeros(1,1024-32)];
X_padded = fft(x_padded);
X = fft(x);

figure;
plot(2048/1024*(0:1023), abs(X_padded)); hold on;
stem((0:31)*64, abs(X));
xlabel('Frequency (Hz)');
ylabel('|X|');
ylim([0 16])
xlim([0 1024])
xticks([0:9]*110)
```



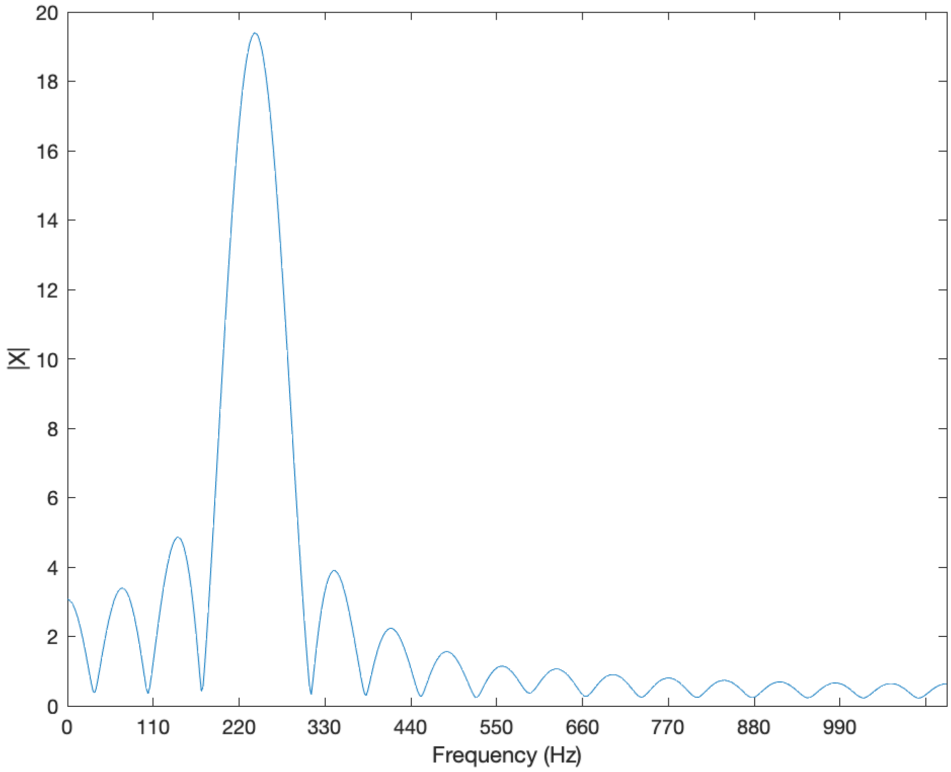
[1-2]



The plot shows a peak at 128 Hz, which corresponds to the frequency of the sinusoid. The magnitude of the peak is also correct.

Compared to the plot in problem 1.1, the peak in this plot is narrower. This is because the frequency resolution is higher when the sequence is longer. In other words, we can more accurately determine the frequency of the sinusoid when we have more samples.

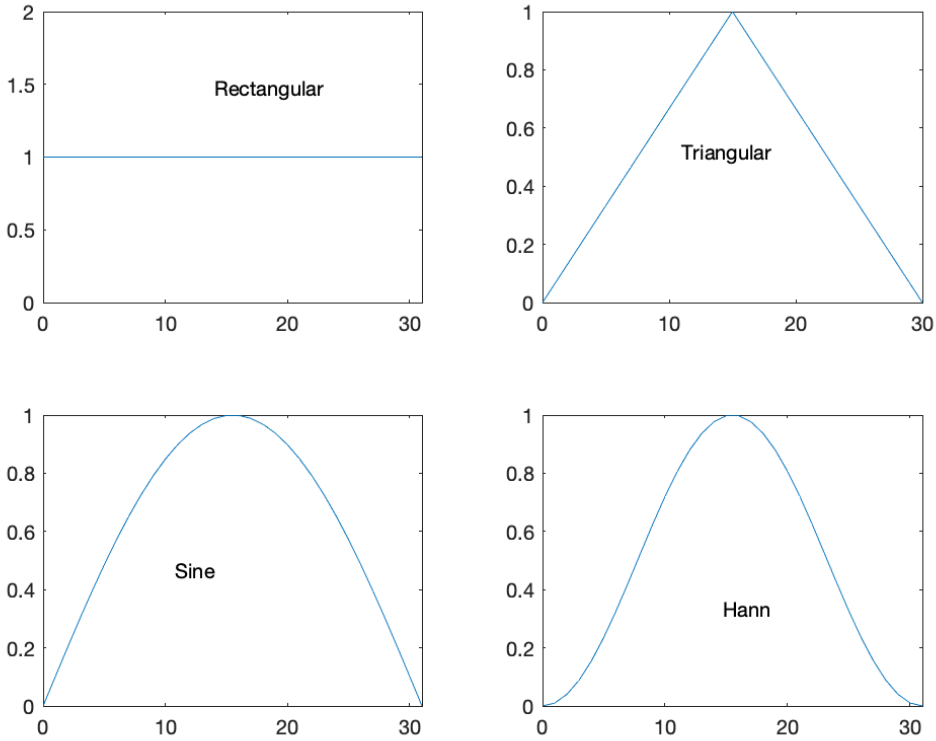
[1-3]



[1-4]

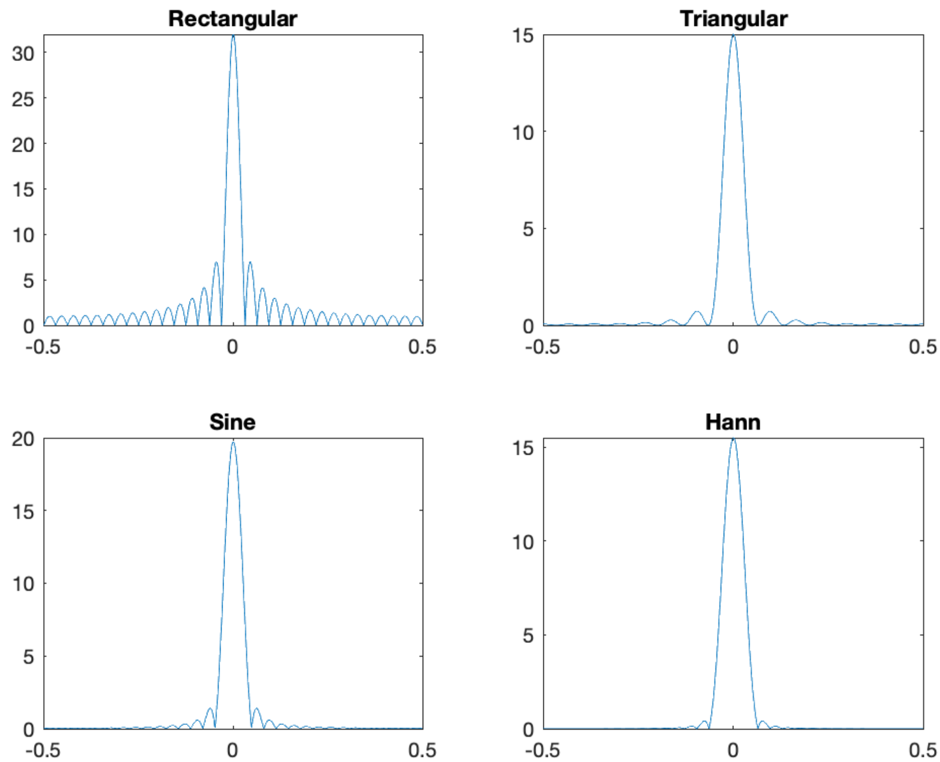
No, it is not possible to pick out the right frequency components in the magnitude spectrum without knowing that there are multiple pure tones in the sequence.

[2-1]



Rectangular
Triangular
Sine
Hann

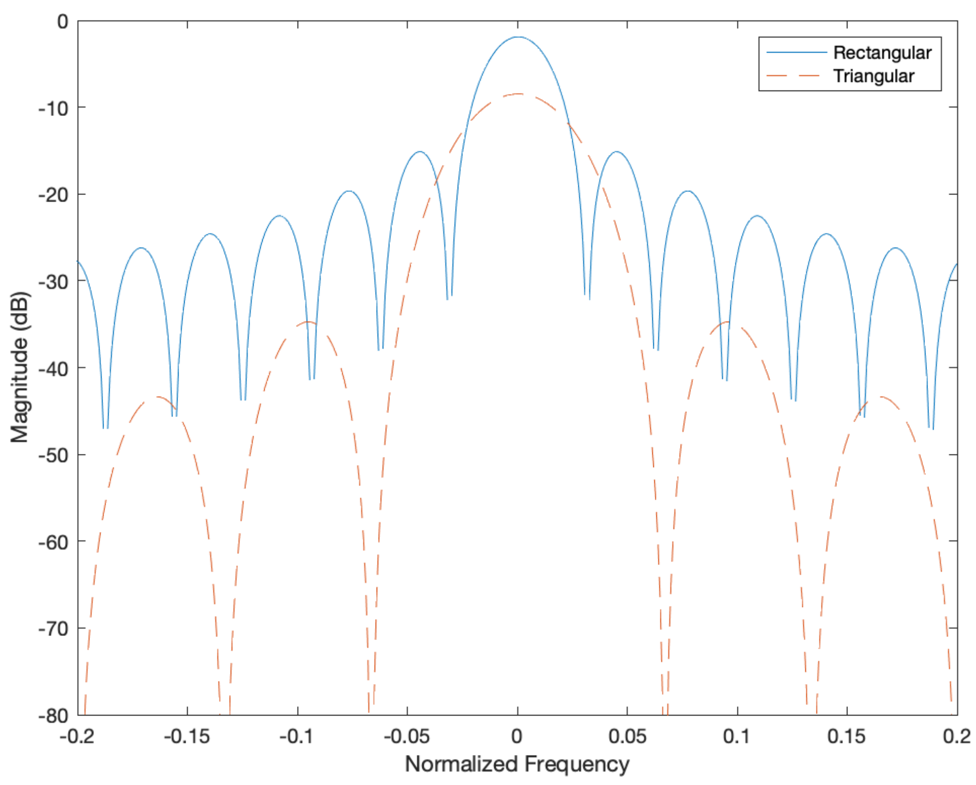
[2-2]



Rectangular
Triangular
Sine
Hann

[2-3]

```
w1=arrayfun(@(n) 1, (0:31));

w2=arrayfun(@(n) (15-abs(n-15))*2/30, (0:30));

W1=abs(fft(w1, 1024));

W2=abs(fft(w2, 1024));

rect = 20 * log10(abs(fftshift(W1)));

tri = 20 * log10(abs(fftshift(W2)));

plot(linspace(0, 1, length(W1)), rect); hold on;

plot(linspace(0, 1, length(W2)), tri, '--');

legend(["Rectangular", "Triangular"])

xlim([0.3 0.7])

xticks([0.3:0.05:0.7])

xticklabels((0.3:0.05:0.7)-0.5)

xlabel('Normalized Frequency');

ylim([-80 0]+32)

yticks([-80:10:0]+32)

yticklabels([-80:10:0])

ylabel('Magnitude (dB)');
```

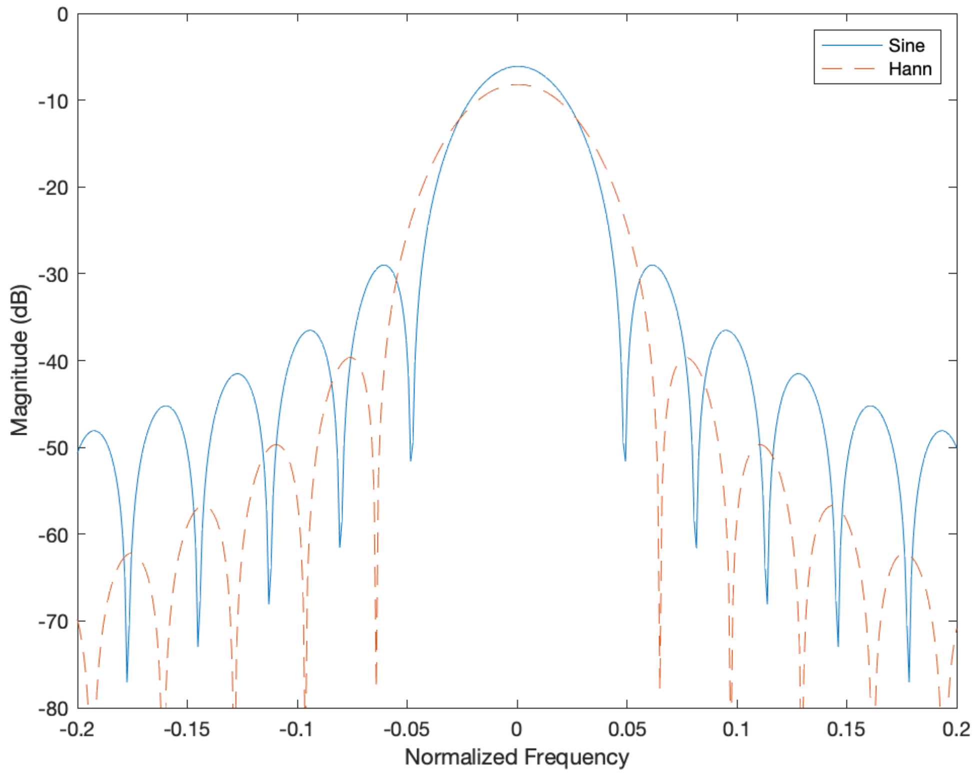


[2-4]
Width of main lobe (Rectangular): about 0.05
Width of main lobe (Triangular): about 0.14

The rectangular window has sharp transitions at its edges, while the triangular window has smoother transitions.

[2-5]
Height of the first side-lobe (Rectangular): about -15
Height of the first side-lobe (Triangular): about -35

[2-6]



[2-7]
Width of main lobe (Sine): about 0.1
Width of main lobe (Hann): about 0.14

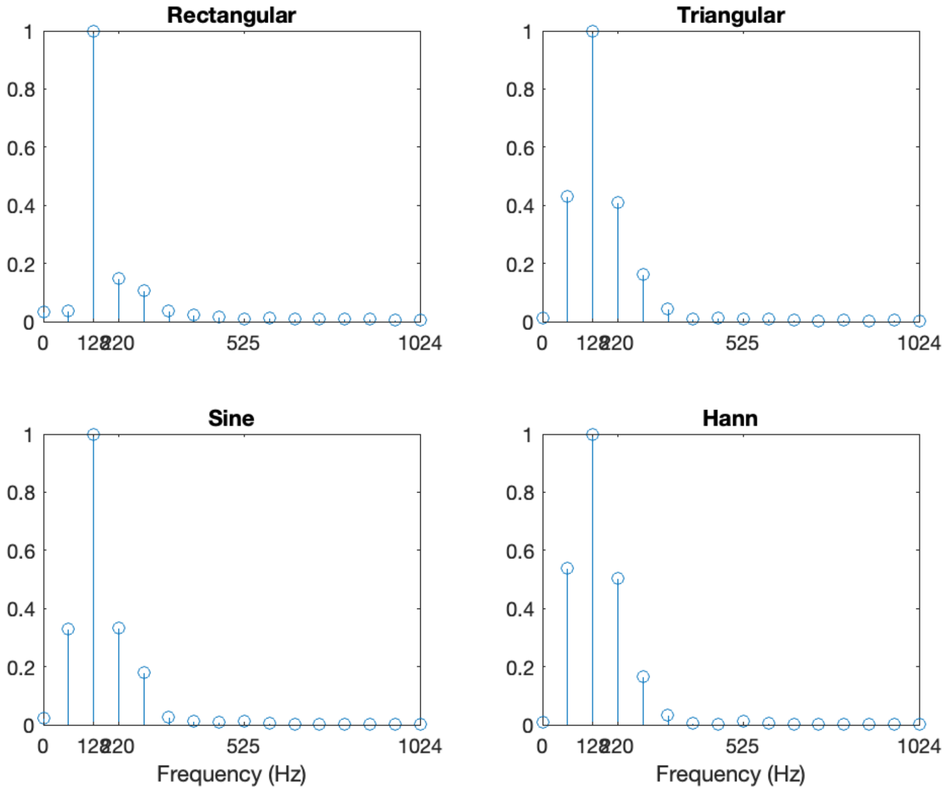
The Hann window has a smoother transition at its edges than the sine window, which results in a wider main lobe and reduced side lobes.

[2-8]
Height of the first side-lobe (Sine): about -28
Height of the first side-lobe (Hann): about -40

[3-1]

```
x = sin(2*pi*128*n/2048)+0.2*sin(2*pi*220*n/2048)+0.01*cos(2*pi*525*n/2048);
w1=arrayfun(@(n) 1, (0:31));
w2=arrayfun(@(n) (15-abs(n-15))*2/30, (0:30));
w3=arrayfun(@(n) sin(pi*n/31), (0:31));
w4=arrayfun(@(n) 0.5*(1-cos(2*pi*n/31)), (0:31));

subplot(2,2,1)
stem((0:31), abs(fft(x.*w1))./max(abs(fft(x.*w1))))
title('Rectangular')
xlim([0 15])
xticks([0 2 3 8 15])
xticklabels([0 128 220 525 1024])

subplot(2,2,2)
stem((0:31), abs(fft(x.*[w2 0]))./max(abs(fft(x.*[w2 0]))))
title('Triangular')
xlim([0 15])
xticks([0 2 3 8 15])
xticklabels([0 128 220 525 1024])

subplot(2,2,3)
stem((0:31), abs(fft(x.*w3))./max(abs(fft(x.*w3))))
title('Sine')
xlim([0 15])
xticks([0 2 3 8 15])
xticklabels([0 128 220 525 1024])
xlabel('Frequency (Hz)')

subplot(2,2,4);
stem((0:31), abs(fft(x.*w4))./max(abs(fft(x.*w4))))
title('Hann')
xlim([0 15])
```

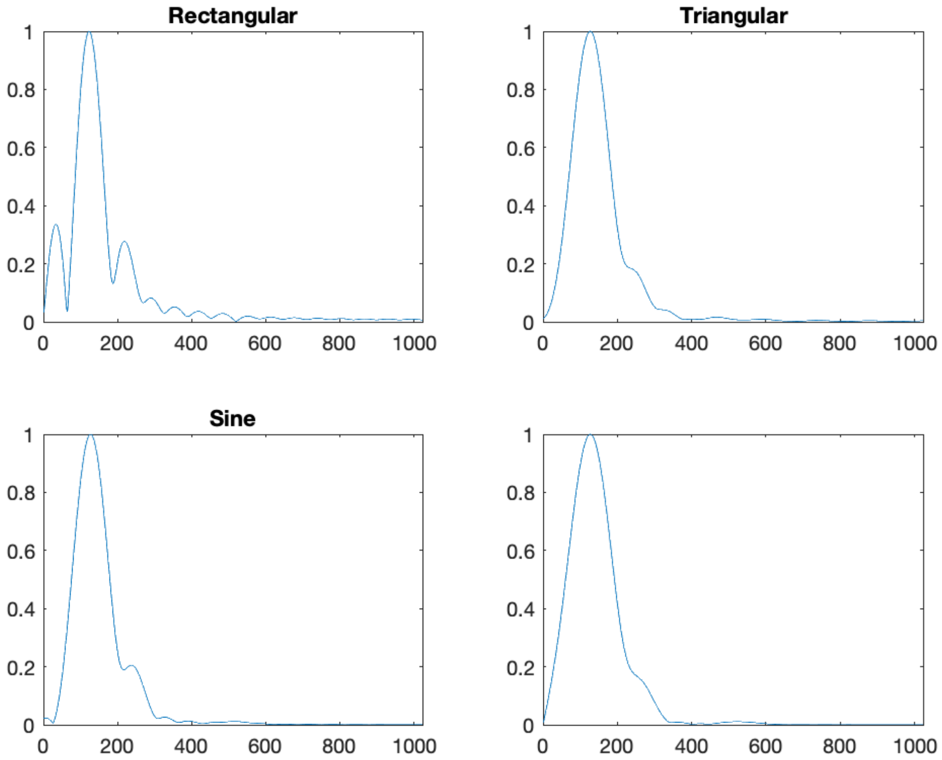
```
xticks([0 2 3 8 15])
xticklabels([0 128 220 525 1024])
xlabel('Frequency (Hz)')
```



[3-2]

```
x = sin(2*pi*128*n/2048)+0.2*sin(2*pi*220*n/2048)+0.01*cos(2*pi*525*n/2048);
w1=arrayfun(@(n) 1, (0:31));
w2=arrayfun(@(n) (15-abs(n-15))*2/30, (0:30));
w3=arrayfun(@(n) sin(pi*n/31), (0:31));
w4=arrayfun(@(n) 0.5*(1-cos(2*pi*n/31)), (0:31));


subplot(2,2,1)
plot((0:2047), abs(fft(x.*w1, 2048))./max(abs(fft(x.*w1, 2048))))
title('Rectangular')
xlim([0 1023])


subplot(2,2,2)
plot((0:2047), abs(fft(x.*[w2 0], 2048))./max(abs(fft(x.*[w2 0], 2048))))
title('Triangular')
```

```
xlim([0 1023])


subplot(2,2,3)

plot((0:2047), abs(fft(x.*w3, 2048))./max(abs(fft(x.*w3, 2048))))

title('Sine')

xlim([0 1023])


subplot(2,2,4);

plot((0:2047), abs(fft(x.*w4, 2048))./max(abs(fft(x.*w4, 2048))))

xlim([0 1023])
```



[3-3-1]
Can only say that this signal has three components using the sine window. This is because the sine window has the narrowest main lobe and the lowest side lobes, which allows to see the three components more clearly.

[3-3-2]
The sine window will provide the most accurate result. This is because the sine window has the narrowest main lobe, which means that the frequency of the middle amplitude sinusoid will be the most accurately represented in the frequency spectrum.

[3-3-3]
Because the sine and Hann windows are good at revealing the lowest amplitude component because they have lower side lobes than the rectangular window.

[3-3-4]
The lowest amplitude component should have a normalized dB level of -40 dB because this is the level at which it will be barely visible in the frequency spectrum.