ANSWER SCRIPT COVER PAGE

NED University of Engineering & Technology

Online Fall Semester Examinations - 2020-2021

Seat No. BM17040 Batch 2017

Course Title: Biosignal Processing Course Code : BM-451

Enrol No. NED/1382/2017 Date : 13 Feb 2021

Question No.	Award	
	First Examiner/ Internal	Second/ External Examiner/ ERC
1.		
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12.		
Total in figures		
Total in words		

PLEASE READ THESE INSTRUCTIONS CAREFULLY

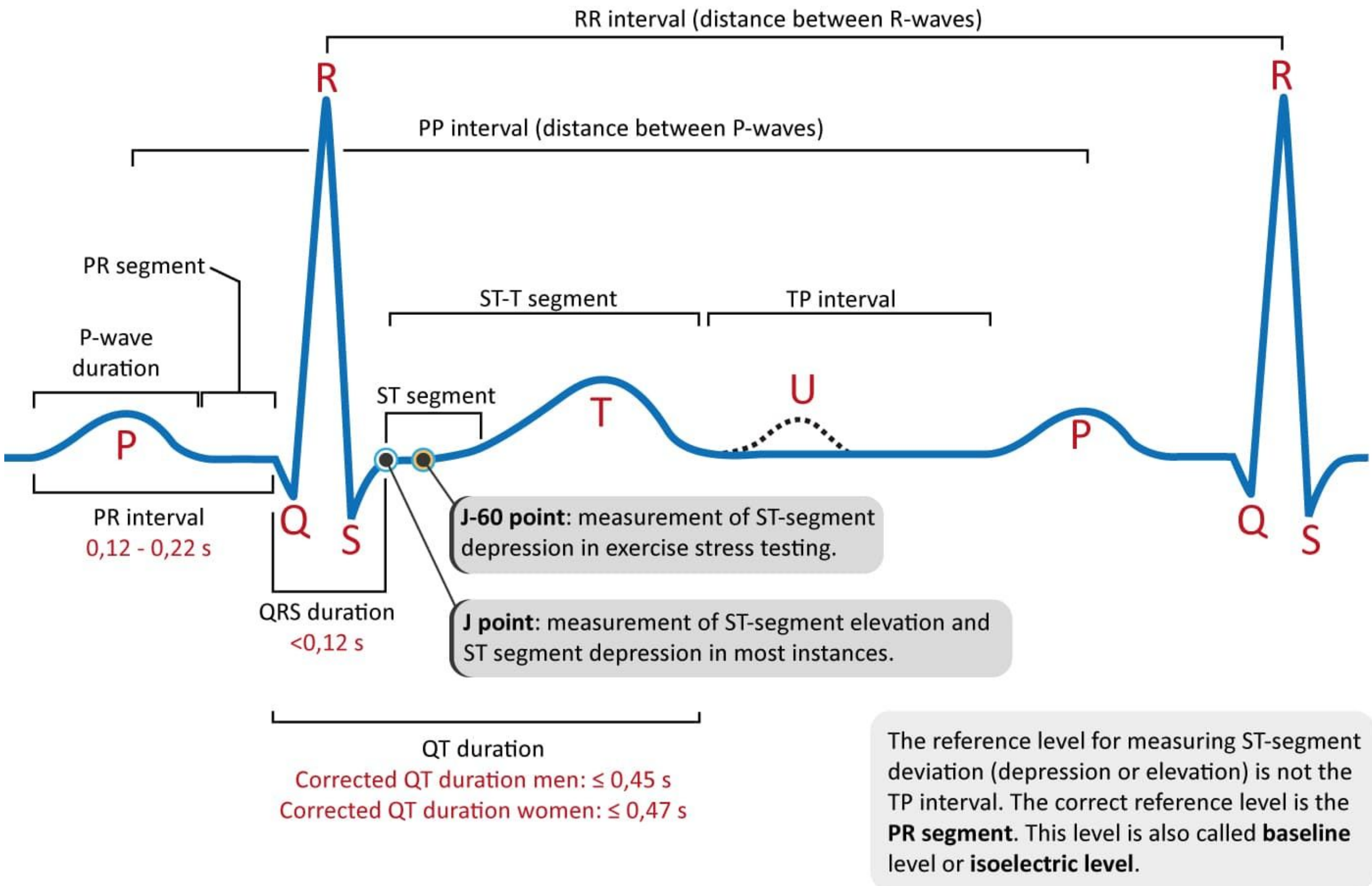
1) Download and print this cover page (separately for each exam).
2) Fill the above mentioned particulars before attempting the questions.
3) Students are not allowed to use red or green ink. Solve the questions on A4 size paper using blue or black pen ONLY.

First / Internal Examiner's Signature

Second / External Examiner's / ERC Signature

Question # 1 - Share some common features extracted from ECG or EMG or EEG data? Explain practical importance of each feature (applications). It is suggested to present the answer with the help of equations (where applicable).
[CLO1, PLO1, C2] [20 Marks]

Features of ECG.



PR Interval

The PR interval is the time from the onset of the P wave to the start of the QRS complex. It reflects conduction through the AV node.

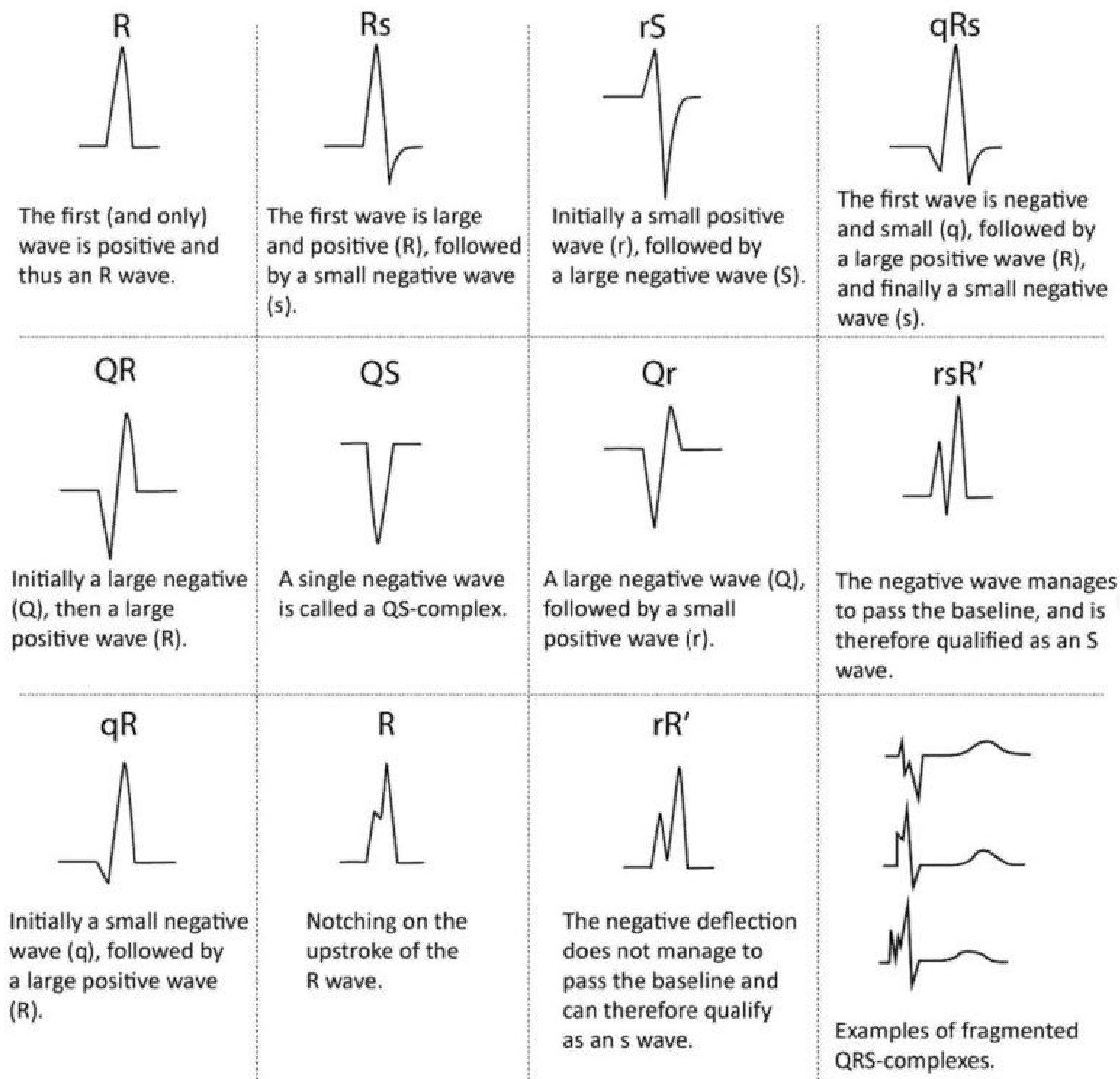
- The normal PR interval is between 120 – 200 ms (0.12-0.20s) in duration (three to five small squares).

Application of PR Interval

- If the PR interval is > 200 ms, first degree heart block is said to be present.
- PR interval < 120 ms suggests pre-excitation (the presence of an accessory pathway between the atria and ventricles) or AV nodal (junctional) rhythm.

QRS Complex

- Width of the complexes: Narrow versus broad.
- Voltage (height) of the complexes.
- Spot diagnosis: Specific morphology patterns that are important to recognise.

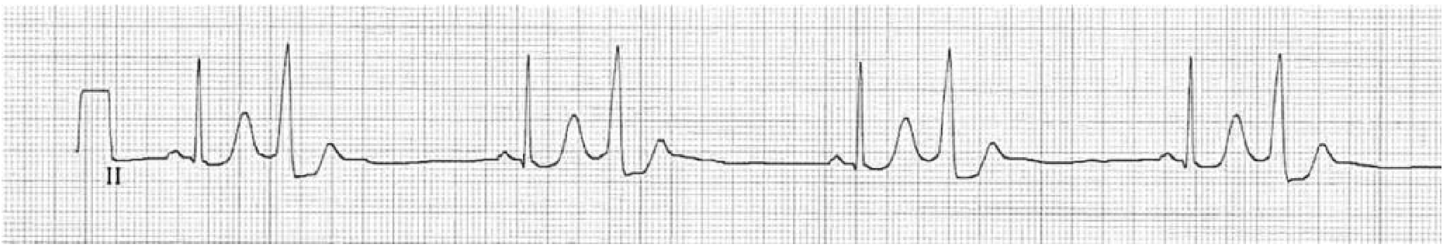


Application of QRS Complex

QRS Width

Normal QRS width is 70-100 ms (a duration of 110 ms is sometimes observed in healthy subjects). The QRS width is useful in determining the origin of each QRS complex (e.g. sinus, atrial, junctional or ventricular).

- Narrow complexes (QRS < 100 ms) are supraventricular in origin.
- Broad complexes (QRS > 100 ms) may be either ventricular in origin, or due to aberrant conduction of supraventricular complexes (e.g. due to bundle branch block, hyperkalaemia or sodium-channel blockade).



Example ECG showing both narrow and broad complexes

Sinus rhythm with frequent ventricular ectopic beats (VEBs) in a pattern of ventricular bigeminy. The narrow beats are sinus in origin, the broad complexes are ventricular.

ST - Segment

The ST segment is the flat, isoelectric section of the ECG between the end of the S wave (the J point) and the beginning of the T wave.

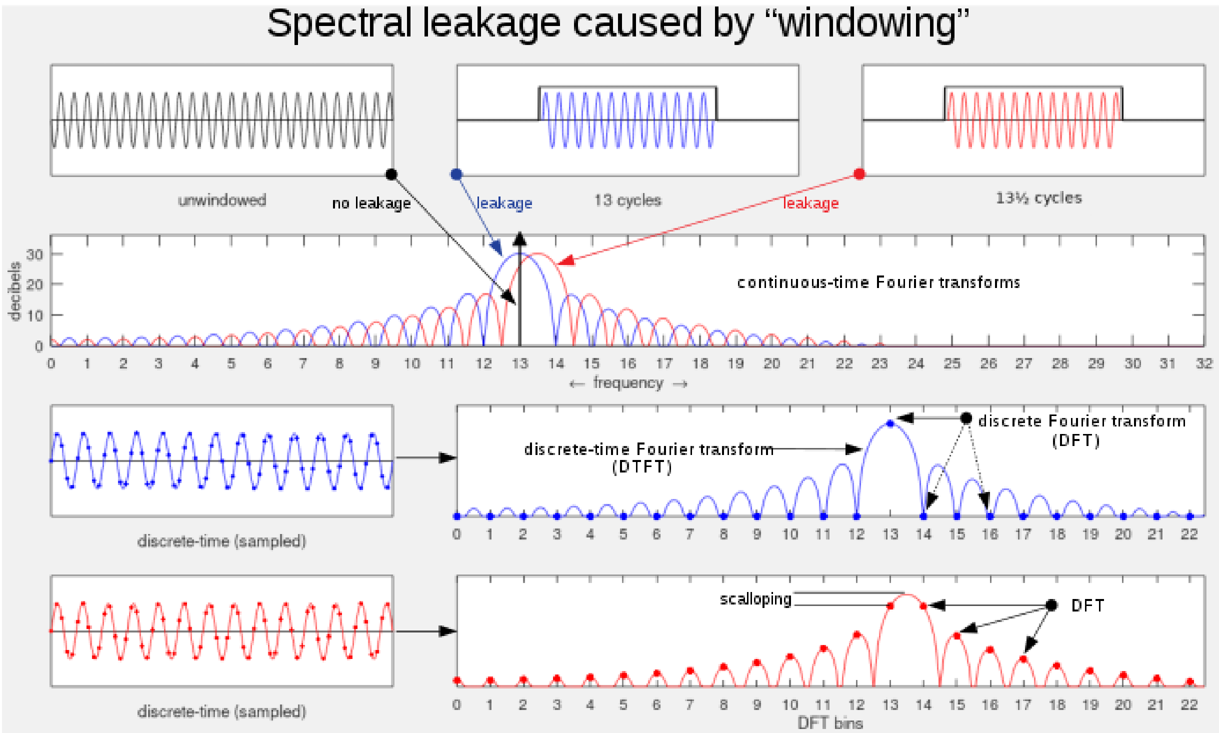
Application of ST Segment

- The ST Segment represents the interval between ventricular depolarization and repolarization.
- The most important cause of ST segment abnormality (elevation or depression) is myocardial ischaemia or infarction.

Question # 2 - Explain the concepts of spectral leakage and variance? Mention whether these two issues appear in which domain of signal processing (time, frequency, time-frequency)? How do we resolve these two issues? Support your answer with the help of figures and numbers?
[CLO1, PLO1, C2] [20 Marks]

Spectral Leakage

Spectral leakage occurs when a non-integer number of periods of a signal is sent to the DFT. Spectral leakage lets a single-tone signal be spread among several frequencies after the DFT operation. This makes it hard to find the actual frequency of the signal.



Spectral Variance

Summation or integration of the spectral components yields the total power (for a physical process) or variance (in a statistical process).

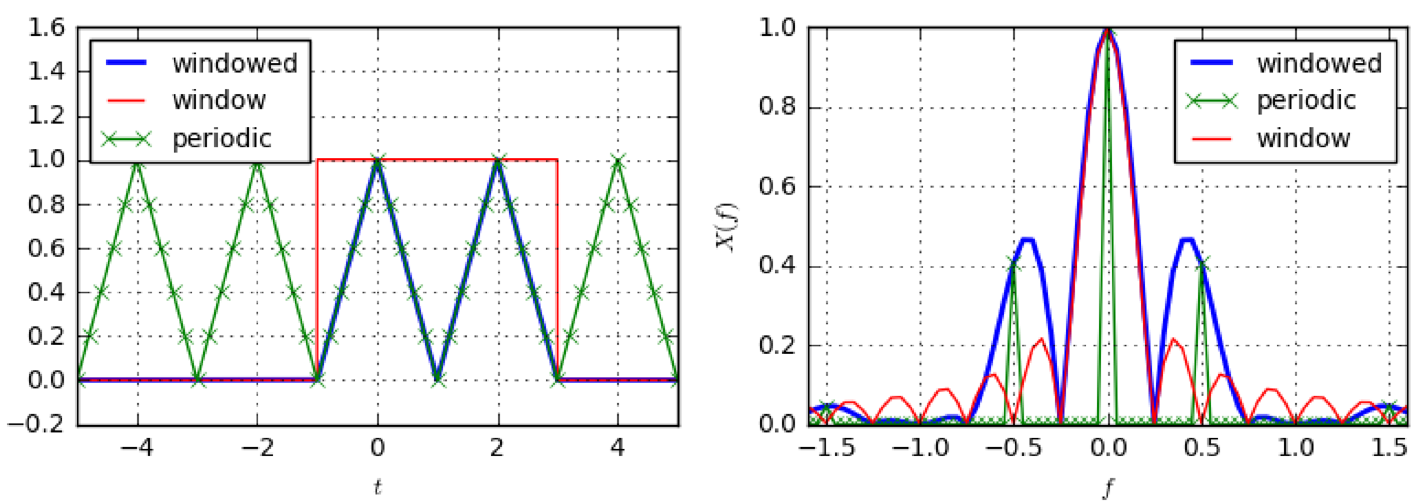
$$P = \mathrm{Var}(x) = \int_{-\infty}^{\infty} S_{xx}(f)\,df$$

Minimizing Spectral Leakage

Increasing the sampling frequency, thereby generating longer discrete-time sequences for equivalent sampling times, reduces spectral leakage, but does not eliminate the problem. One popular method for mitigating spectral leakage in the DFT estimation of spectral content is called data windowing . In this method, the original signal $x[n]$, $n \in \{0, 1, \ldots, N-1\}$, is modified by multiplication with a windowing function that approaches zero near $n = 0$ and $n = N-1$, and reaches a peak of one near $n = N/2$. While there are many possible choices of windowing functions, one popular choice is the Hamming window function $h[n]$, which is given below:

$$h[n] = 0.54 - 0.46\cos\left(\frac{2\pi n}{N-1}\right),\ n \in \{0, 1, \ldots, N-1\}.$$

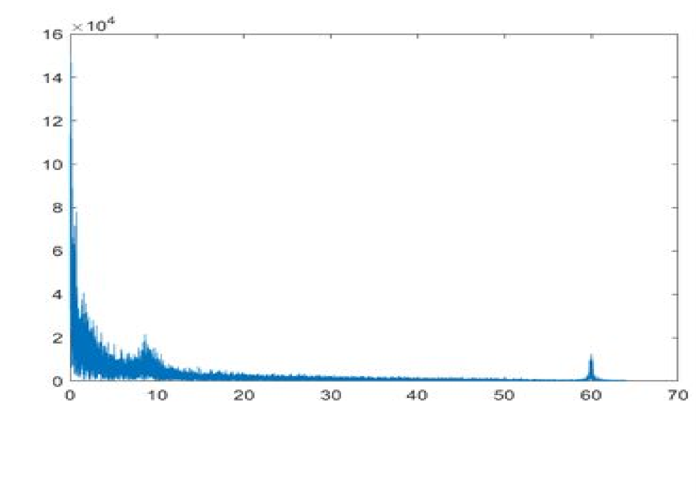
```
def rect(t):
    return (abs(t)<0.5).astype(float)
window = lambda t: rect((t-1)/4)
def windowed_periodic_triang(t):
    return periodic_triang(t) * window(t)

plt.subplot(121)
plt.plot(t, windowed_periodic_triang(t), 'b-', label='windowed', lw=2);
plt.plot(t, window(t), 'r-', label='window')
plt.plot(t, periodic_triang(t), 'g-x', label='periodic', markevery=2000)

cft_windowed_periodic_triang = cft(windowed_periodic_triang, f) / 2
cft_window = cft(window, f) / 4
plt.subplot(122)
plt.plot(f, abs(cft_windowed_periodic_triang), 'b-', label='windowed', lw=2);
plt.plot(f, abs(cft_periodic_triang), 'g-x', label='periodic')
plt.plot(f, abs(cft_window), 'r-', label='window')
```

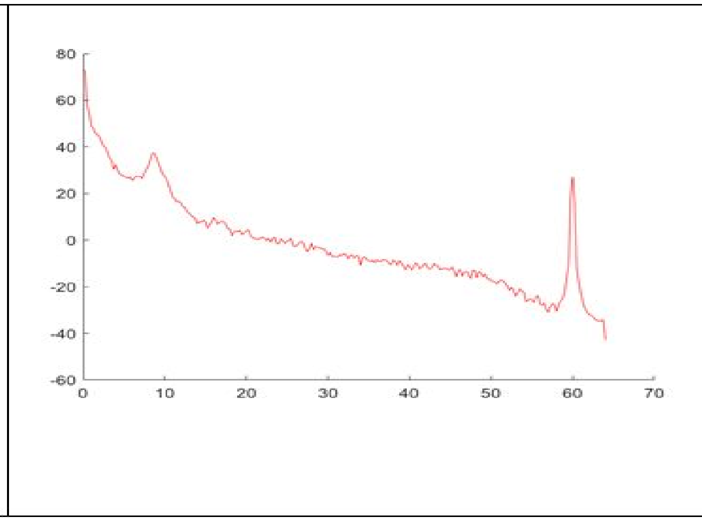


Minimizing Variance

Divide the data sequence into small overlap and or non-overlap segments (K-segments). Variance is reduced by a factor K but the frequency resolution is reduced by a factor K.

Question # 3 - Explain difference between two figures based on signal processing perspective?



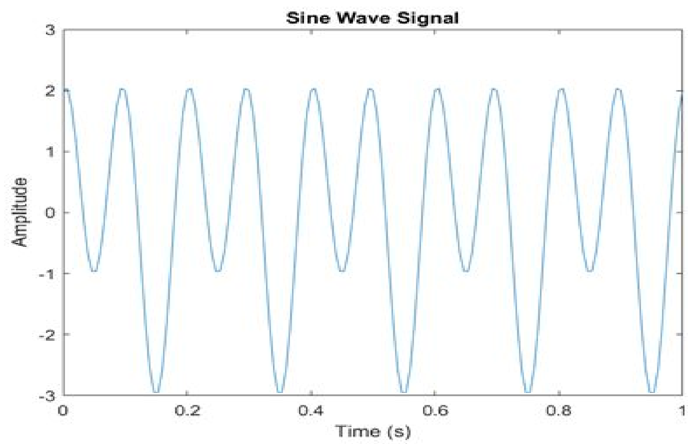


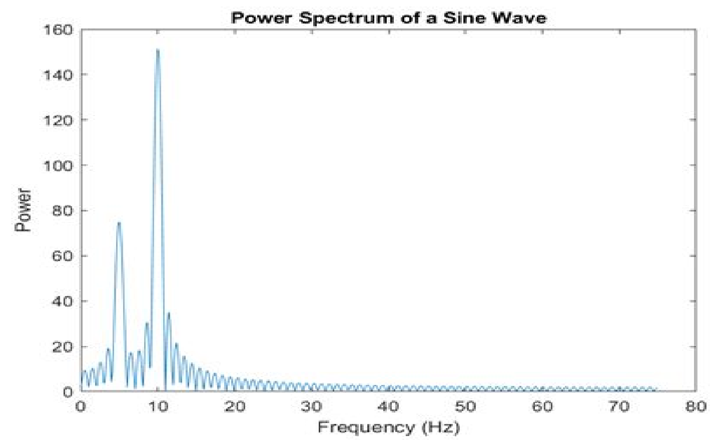
Answer # 3

Fig # 1	**Fig # 2**
Absolute values in a Frequency Spectrum of a Signal DFT of a signal collected in the time domain using fft.	**Power Spectrum Density (PSD) of the Signal using hamming window and pwelch**
Signal has frequencies ranging from 0 to 70 Hz	Signal has frequencies ranging from 0 to 70 Hz
Signal has to much noise	Signal Has less noise
Amplitude of dominant Frequencies is low	Amplitude of dominant Frequencies is greater
Signal to Ratio (SNR) is low	SIgnal to Noise Ratio (SNR) is better
Line noise of 60Hz is mildly noticeable	Line Noise of 60Hz is clearly noticeable.

`clear all`
`load x`
`Fs=128;`
`t = 0:1/Fs:(238.3125-1/Fs);`
`plot(t,x)`
`X = fft(x(1,:),length(x));`
`% FFT is symmetric, throw away second half`
`X = X(1:length(X)/2);`
`% Take the magnitude of fft of x`
`mx = abs(X);`
`% Frequency vector`
`f = (0:(length(X)/2)-1)*Fs/(length(X)/2);`
`figure`
`plot(f,mx)`
	`clear all`
	`load x`
	`Fs=128;`
	`[x_psd, fw] = pwelch(`
	`    x(1,:),`
	`    hanning(512),`
	`    128,`
	`    512,`
	`    128`
	`);`
	`hold on`
	`plot(fw,10*log(x_psd),'r')`

Question # 4 - Explain difference between two figures based on their equations and signal processing perspective?





Answer # 4

Sine Wave Signal (Fig #1)	**Power Spectrum of Sine Wave (Fig # 2)**
Mathematical Expression x(t) = sin(2*pi*5 * t) + 2sin(2*pi* 10*t)	**Mathematical Expression** ● Original Signal ○ x(t) = sin(2*pi*5 * t) + 2sin(2*pi* 10*t) ● Take Fast Fourier Transform ○ y = fft(x) ● Calculate Power manually or using pwelch ○ y = abs(y).^2 ○ pwelch(x)
Signal is in the time domain.	Signal is in the Frequency domain.
Contains Frequencies which cannot be determined by looking at the graph	Frequencies can be determined that have the most power in the signal i.e the Main Lobes or give the SNR (signal to noise ratio) the side lobes are because of spectral leakage.

`fs = 512; % Sampling frequency (samples per second)`
 	
`dt = 1/fs; % seconds per sample`
 	
`dur = 1; % seconds`
 	
`t = (0:dt:dur)'; % seconds`
 	
`f1 = 5; % Sine wave frequency (hertz)`
`f2 = 10;`
`x = sin(2*pi*f1*t) + 2 * cos(2*pi*f2*t) ;`
	`fs = 512; % Sampling frequency (samples per second)`
	
	`dt = 1/fs; % seconds per sample`
	
	`dur = 1; % seconds`
	
	`t = (0:dt:dur)'; % seconds`
	
	`f1 = 5; % Sine wave frequency (hertz)`
	`f2 = 10;`
	`x = sin(2*pi*f1*t) + 2 * cos(2*pi*f2*t) ;`
	`y = fft(x);`
	`freq_ampl = abs(y).^2;`

	`angles = angle(y);`