University of Pennsylvania
Department of Electrical and System Engineering
Digital Signal Processing

ESE531, Spring 2019 | HW9: DFT, FFT | Sunday, Apr. 7

Due: Sunday, Apr 14, 11:59PM

- **Recommended Problems for Practice:** From the book: 8.28, 9.28, 9.33ab
- **Homework Problems:** All problems must be turned in and are not optional for full credit
- Homework problems from the book: 8.40, 8.43, 9.32
- Matlab problem 1: Let $x[n]$ be a discrete time sequence:

$$x[n] = \begin{cases} (0.7)^n 0 \leq n \leq 7 \\ 0 \text{else} \end{cases} \tag{1}$$

  a) Determine the analytical expression for the DTFT of $x[n]$ and plot the magnitude and phase of the DTFT.
  b) Compute in MATLAB the 8-point DFT of $x[n], 0 \leq n \leq 7$ using the `fft` function. Plot the magnitude and phase. Use the `stem, abs, angle` commands.
  c) Compute, in MATLAB, the 16-point DFT of $x[n], 0 \leq n \leq 15$ and stem plot its magnitude and phase. Comment on the effect of zero-padding the signal on its DFT.
  d) Compute, in MATLAB, the 128-point DFT of $x[n], 0 \leq n \leq 127$ and plot its magnitude and phase. Note: the plot command is used instead of stem when many dense points exist to avoid appearance of a black blob.
  e) Compare the results from part (d) to the plots of part (a). How does this relate to the relationship between digital frequency ω and DFT index k?

- Matlab problem 2: Consider the following two sequences:

$$x[n] = [1111]$$
$$y[n] = [1111]$$

  a) Perform the linear convolution of the two sequences using the `conv` command. Plot the result using stem.
  b) Analytically perform the circular convolution of the two sequences.

c) Compute the DFT of $x[n]$ and $y[n]$. Store the result in vectors X_k and Y_k. Now perform a point-by-point product of X_k and Y_k. i.e. compute $Z_k = X_k. * Y_k$. Take the inverse DFT of Z_k. In case you get complex valued outputs, extract the real part using the `real` command. Verify that your result agrees with the result obtained in Part (b). Plot your result using stem. How many samples of the result agree with the result in Part (a)?

d) Increase the length of $x[n]$ and $y[n]$ by zero-padding the sequences. First add one zero to both the sequences. Repeat the steps in Part (b). How many samples agree with the result in Part (a)? How many zeros will be needed to obtain the result in Part (a)?

- Matlab problem 3: Download the file tones.mat from the course calendar. The file contains the a signal which has multiple tones in it. Load the signal using the following commands,

```
s = load(tones.mat);
x = s.y1;
```

The variable x should now contain the signal.

a) Compute the DFT of x using a transform length N = 25. Plot the magnitude of the DFT using the plot command. How many distinct frequencies do you see?

b) Experiment with the sequence length (by adding a different number of zeros). Compute the DFT for these different sequence lengths obtained by zero-padding. Can you find more frequencies? How many tones can you distinguish and what are their values?