ECE521 Experiment # 3: On Digital Filters Design  
(Issued Tuesday 6/26, Due Tuesday 7/10)

The purpose of this experiment is the following:
1. Studying the frequency response of common window functions, and
2. Designing a general purpose FIR digital filter based on the windowing method.

1 Spectral Analysis of Windows

The purpose of this part is to study the frequency spectrum of window functions. These windows are to reduce the leakage effect, and as a result improve the accuracy of the frequency spectrum. Common window functions are in the textbook, Chap. 7. We are interested in four windows: the rectangular window, the Bartlett (triangular) window, the Hamming window, and the Kaiser window. The algorithm to evaluate the function \( I_0(.) \) can be found in Chap. 7. Using a window length \( L = 256 \), obtain the sequence \( w[n] \) of the four windows and evaluate the function \( W(f_d) \). Plot one period for \(-0.5 \leq f_d \leq 0.5\) for all windows on the same scale with the amplitude in dB. Compare the width of the main lobe for all windows and the stop band (side lobes) attenuation.

2 FIR Digital Filter Design

In this part we will design a general purpose FIR digital filter using the windowing method. We will consider only the four windows of Part 1 (Rectangular, Bartlett, Hamming, and Kaiser) with the number of samples \( N \) even or odd. The program should be interactive with prompts for the following:

A. Filter type

   (A.1) filter type: lowpass, highpass, bandpass, and bandstop;  
   (A.2) window type: rectangular, Bartlett, Hamming, and Kaiser; and  
   (A.3) window length \( N \) (\( N \) is odd for highpass and bandpass filters).

B. Filter specifications

   (B.1) Cutoff frequency \( c \) (we consider only one period of \( f_d \) and the positive frequency range, i.e., \( c \in [0, 0.5] \)) for the two bands \( c_0 \) and \( c_1 \); and  
   (B.2) Attenuation in the stopband. See Chap. 7 of the textbook for how to relate the window length with stopband attenuation to get the parameter \( \beta \) for the Kaiser window.

C. Output format

   (C.1) An option to print the impulse response \( w[n] \) if desired;  
   (C.2) An option to print the frequency response \( W(f_d) \) in dB if desired;  
   (C.3) An option to print the frequency response \( W(f_d) \) in complex form if desired;  
   (C.4) An option to print the sampled frequency response \( w[k], k/N = f_d \) in complex form if desired; and  
   (C.5) An option to loop again to the design process and/or to exit the program.

Test your program using the test problems and tables in the text and the notes and print out a sample result.

**Note:** Write a neat report. All figures should have meaningful captions, properly labeled, and referred to in the text. Refrain from using any handwritten symbols, equations, etc. in your report, use a word-processor