By popular request, this homework has more textbook problems. The relevant MATLAB `.m/.mat` files can be found in a zip archive on Ed: `homework6.zip`. In all problems, include all your plots and code files. It might help to use MATLAB live scripts.

Problem 1 *Short time Fourier transform in MATLAB* 10 points

Load the file `ECG_1hr.mat` which contains one hour of electrocardiogram signal in the variable `ecg`. Plot the time-frequency spectra of this signal using the `stft` approach shown in Example 4.8 of CSSB. You can find the necessary `stft.m` file in the archive. Limit the frequency range to 3 Hz and do not include the DC component. Note the sampling frequency is 250 Hz. This is Problem 4.20 of CSSB.

Problem 2 *System ID in MATLAB* 15 points

Read Example 5.1 in CSSB carefully. Modify the code to find the maximum length of a pulse that will serve as an impulse to system represented by the MATLAB function, `unknown_sys_hw6.m`. Note this system has quite different response characteristics and the maximum pulse width will also be quite different compared to the example. You need to look at complete impulse response to determine the maximum pulse width, but this system is much slower than the one in the example. Therefore, increase the time interval under observation accordingly.

Problem 3 *Convolution and Fourier transforms* 10 points

(a) Prove that the convolution operator is commutative:

$$f(t) \star g(t) = g(t) \star f(t)$$

(b) Find the inverse Fourier transform of the frequency domain impulse function $\delta(\omega)$.

Problem 4 *Basic convolution* 15 points

Use the basic convolution equation (Eq. 5.1) to find the output of a system with an impulse response shown below to a step input with amplitude 3; i.e, $x(t) = 3$ for $t > 0$.

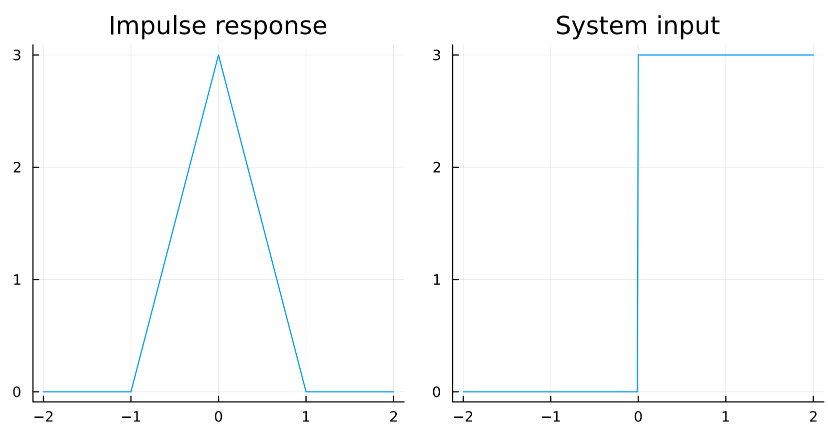

Figure 1: Find the system response.

Problem 5 *Do Problem 5.11 of CSSB* 15 points

This problem looks intimidating but can be solved in about 15 lines of MATLAB code (excluding the plotting commands). Make good use of the hints given in the problem:

- Use a loop to evaluate sinusoids of frequency between 1 Hz to 50 Hz. Make the length of these signals $N = 256$ so DFT is faster.
- Use a sampling frequency of $f_s = 100$ Hz. This means the frequency needs to be plotted between $[0, 50]$ Hz.
- Make the amplitude of the sine wave $\sqrt{2}$ so that the RMS value of the input is 1.

Problem 6 *Moving averages as filters* 10 points

Load the respiratory signal `resp` in file `resp_noise.mat` sampled at 125 Hz. Apply a 3-point moving average filter and a 12-point moving average filter. If you use MATLAB's `filter(h, 1, x)` command it will produce a filtered signal that is the same length as the input signal. Display the results from the two filters in two plots using subplot. Each plot should compare the unfiltered signal with one of the filtered signals. Title the plots and offset the filtered signal (by 1.0) for better viewing. Note the improved noise reduction with the 12-point moving average filter. This is Problem 5.13 in CSSB.

Problem 7 *Phase characteristics* 10 points

Show both the magnitude and phase spectra of two filters, one a four-point moving average and the other the four-coefficient "Daubechies" filter used in Problem 5 above. Use $f_s = 200$ Hz and adequate padding. Plot phase in degrees and plot only valid points. Use subplot to bring the four plots together. This is Problem 5.14 in CSSB.

Problem 8 *Mystery filter* 15 points

Load the MATLAB file `filter1.mat`, which contains the impulse response, `h`, of a mystery filter. Also load the signal in `cardiac_press.mat`, which holds one cycle of a cardiac pressure wave in variable `c_press` which is sampled at 200 Hz. Apply the impulse response, `h`, to the pressure signal using convolution. Plot the cardiac pressure signal before and after filtering on separate plots using subplot. What does this mystery filter do? This is Problem 5.15 in CSSB.