1. **Equalization warm-up:** Calculate and provide the equalizer coefficients for each one of the following channels and situations:

   a. Channel (a), 3-tap FIR zero-forcing equalizer (ZFE) with 2 post-cursors (i.e., \( H(z) \approx 1 + w_1 z^{-1} + w_2 z^{-2} \)), equalizer gain (peak swing) unconstrained.

   b. Same as a., but with equalizer at the transmitter and the peak swing constrained to +/- 1V (i.e., 2V differential peak-to-peak).

   c. Channel (a), 3-tap FIR minimum-mean-squared equalizer (MMSE) with 2 post-cursors (i.e., \( H(z) \approx 1 + w_1 z^{-1} + w_2 z^{-2} \)), SNR = 10.

   d. Channel (a), 3-tap transmit FIR ZFE with 1 pre-cursor and 1 post-cursor (i.e., \( H(z) \approx w_1 z^{-1} + w_2 z^{-2} \)), peak swing constrained to +/- 0.5V (i.e., 1V differential peak-to-peak).

   e. Same as d., but with Channel (b).

   ![Channel (a) and Channel (b)](image)

   Note that you may want to write some code that allows you to calculate the coefficients for equalizers with parameterized numbers of pre- and post-cursor taps for this problem; if you write this code it will also help you complete the next problem.

2. **Equalizer design and link margin:** In this problem we will be dealing with the channel shown below:

   ![Channel](image)

   a. Assuming that the equalizer is implemented at the transmitter, and that the transmitter has a maximum signal swing of +/-200mV (i.e., 400mV differential peak-to-peak), plot the worst-case received voltage signal (i.e., the distance of the received signal from 0V differential with the worst-case ISI) as a function of the number of equalizer taps for an up to 7-tap equalizer. Note that you are free to select how many of the taps are pre- vs. post-cursor for each equalizer length.

   b. Now assuming that residual offset, supply noise, and crosstalk contribute up to +/-25mV of total peak-to-peak voltage error, that the receiver’s input-referred noise \( \sigma_{RX} = 2.5\text{mV} \), and still assuming worst-case ISI, plot the BER vs. the number of equalizer taps.
3. **Auto-regressive channel and DFE:** In this problem we will look at a 10Gb/s link operating over a channel that can be modeled as a simple first-order low-pass filter with a pole \( \omega_o = 2\pi \times 500\text{MHz} \).

   a. Assuming that you have an FIR equalizer with one post-cursor and that the value of the main (cursor) tap is 1, what should the coefficient of the post-cursor be in order to zero out the first post-cursor ISI? In other words, if \( H(z) = 1 + w_1z^{-1} \), what should \( w_1 \) be to cancel the first post-cursor ISI due to the channel? You should provide your answer in terms of \( T_{bit} \) (the bit period of the link) and \( \omega_o \) as well as the actual numerical values based on the parameters given in the problem description.

   b. Using the same equalizer whose coefficient you calculated in part a., what will be the value of the residual ISI for all of the rest of the post-cursor taps?

   c. Still using the same equalizer but including a peak transmit swing constraint of \( \pm0.25\text{V} \) (i.e., 500mV differential peak-to-peak) and ignoring all other error sources, what is the received voltage margin? You should again provide both analytical and numerical answers.

   d. Now let’s see how we can improve the link by adding a 1-tap DFE. How would you redesign the linear equalizer (which has the same peak swing constraint as in part c.) knowing that you have the DFE, and what would be the new voltage margin? Please provide both analytical and numerical answers.

   Note that for this problem, the single post-cursor in the linear FIR equalizer does not need to be immediately adjacent to the cursor – i.e., you can use an equalizer of the form \( H(z) \sim 1 + w_1z^{-N} \).

   e. **Bonus:** Repeat part d., but plot/provide expressions for the voltage margin as a function of the number of DFE taps.