Problem 1.

a) $\delta_p = \delta_s = 0.15$ $\quad \Delta\omega = \omega_s - \omega_p = 0.25\pi$

$\omega_p = 0.5\pi$ $\quad A = -20\log_{10}\underbrace{\delta_{min}}_{\min(\delta_p, \delta_s)}$

$\omega_s = 0.75\pi$ $\quad = -20\log_{10}(0.15) \approx 16.48\,dB$

$$\beta = \begin{cases} 0.1102(A-8.7) & A > 50 \\ 0.5842(A-21)^{0.4} + 0.07886(A-21) & 21 \le A \le 50 \\ 0 & A < 21 \end{cases}$$

$$N = \frac{16.48 - 8}{2.285(0.25\pi)} = 4.71 \approx \underline{5}, \quad \underline{\beta = 0.0},$$

b) same as a)

c) $\delta_s = \delta_p = 0.09$, $\quad A \approx 20.92 \rightarrow \underline{\beta = 0.0}$,

$$N = \frac{20.92 - 8}{2.285(0.2\pi)} = 7.19 \simeq \underline{9},$$

d) $\delta_s = \delta_p = 0.09$ $\quad A$: same as c) $\rightarrow \underline{\beta = 0.0}$,

$\Delta\omega = 0.15\pi$

$$N = \frac{20.92 - 8}{2.285(0.15\pi} = 11.99 \rightarrow \approx \underline{N = 13},$$

2. a) Windowing is "near-optimal" but does not guarantee the filter will meet both ripple specifications.

Optimal design minimizes the max error in both δ_p and δ_s

b)

$$N = 2L+1 = \frac{-10\log_{10}(\delta_p\delta_s) - 13}{14.6(\omega_s - \omega_p)/(2\pi)} = \frac{-10\log_{10}(0.005) - 13}{14.6(0.25\pi)/(2\pi)}$$

$$\approx 5.48 \rightarrow \underline{N = 7},$$

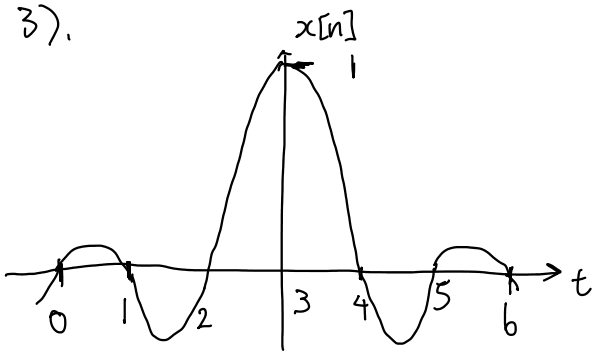
c) $A = -20\log_{10}(0.05) \approx 26.02\,dB$

$$N = \frac{A - 8}{2.285\Delta\omega} = \frac{26.02 - 8}{2.285 \times 0.25\pi} = 10.04 \rightarrow \underline{N = 11},$$

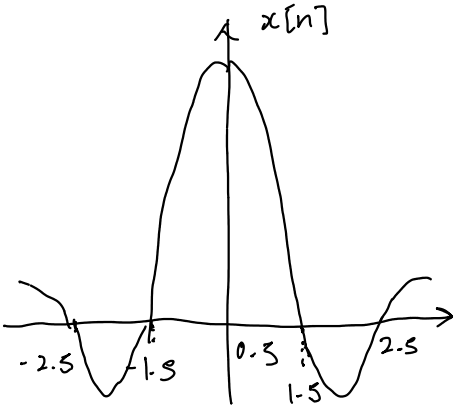
d) $N = 2L + 1 = 7 \rightarrow L = 3$

Problem 3).

a)

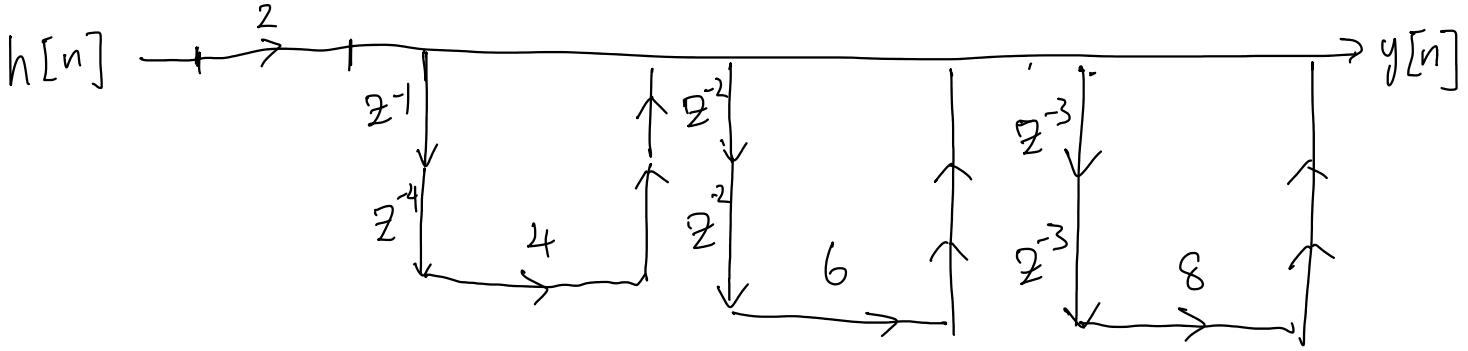


b)



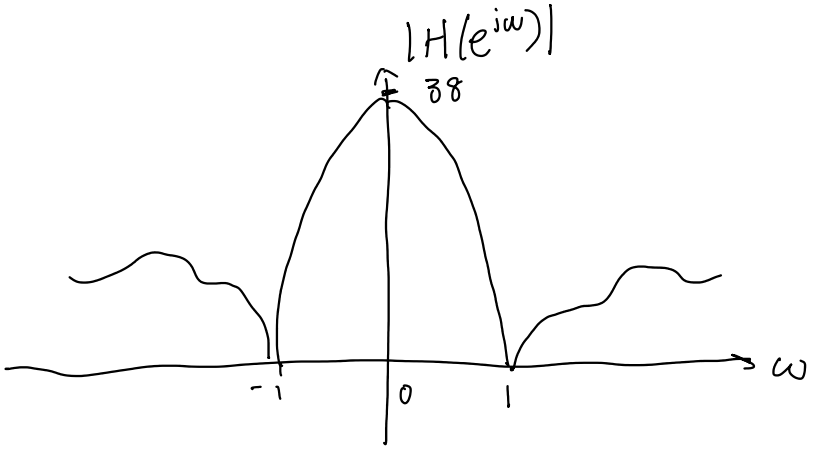
Problem 4. $h[n] = 2\delta[n] + 4\delta[n-1] + 6\delta[n-2] + 8\delta[n-3] + 6\delta[n-4] + 4\delta[n-5] + 8\delta[n-6]$

a) $h[n] = 2\delta[n] + 4(\delta[n-1] + [n-5]) + 6([\delta[n-2] + \delta[n-4]) + 8(\delta[n-3] + \delta[n-6])$



b) $H(e^{j0}) = \sum h[n] = 2 + 4 + 6 + 8 + 6 + 4 + 8 = 38$

$H(e^{j\pi}) = \sum h[n](-1)^n = 2 - 4 + 6 - 8 + 6 - 4 + 8 = 6$



c) No general linear phase

For $N=7$, must be symmetric or anti-symmetric

$h[n] = h[6-n]$ or $-h[6-n]$

$\downarrow$

$h[0] = 2$, $h[6] = 8$, $h[0] \neq h[8]$

d)