23. (a) Solution:
The impulse response is:

$$\begin{aligned} h_{\mathrm{lp}}[n] &= \frac{1}{2\pi}\int_{-\pi}^{\pi} \mathrm{e}^{-\mathrm{j}n_d\omega}\cdot \mathrm{e}^{\mathrm{j}\omega n}\mathrm{d}\omega = \frac{1}{2\pi}\int_{-\pi}^{\pi} \mathrm{e}^{-\mathrm{j}\omega(n-n_d)}\mathrm{d}\omega \\ &= \frac{1}{2\pi}\left(\frac{1}{-\mathrm{j}(n-n_d)}\right)\mathrm{e}^{-\mathrm{j}\omega(n-n_d)}\Big|_{-\pi}^{\pi} = \frac{\sin\pi(n-n_d)}{\pi(n-n_d)} \\ &= \mathrm{sinc}(n-n_d) \end{aligned}$$

(b) Proof:

$$x[n] \xrightarrow{\text{DTFT}} X(\mathrm{e}^{\mathrm{j}\omega})$$
$$Y(\mathrm{e}^{\mathrm{j}\omega}) = X(\mathrm{e}^{\mathrm{j}\omega})\cdot H_{\mathrm{lp}}(\mathrm{e}^{\mathrm{j}\omega}) = X(\mathrm{e}^{\mathrm{j}\omega})\cdot \mathrm{e}^{-\mathrm{j}n_d\omega}$$

Applying time-shifting property, we have

$$y[n] = x[n-n_d]$$

24. tba

25. (a) Solution:

$$\begin{aligned} w[n] &= \left[\frac{1}{2} - \frac{1}{2}\times\frac{1}{2}\left(\mathrm{e}^{\mathrm{j}\frac{2\pi n}{M}} - \mathrm{e}^{-\mathrm{j}\frac{2\pi n}{M}}\right)\right] w_R[n] \\ &= \frac{1}{2}w_R[n] - \frac{1}{4}w_R[n]\cdot \mathrm{e}^{\mathrm{j}\frac{2\pi n}{M}} + \frac{1}{4}w_R[n]\cdot \mathrm{e}^{-\mathrm{j}\frac{2\pi n}{M}} \end{aligned}$$

Hence, we have

$$W(\mathrm{e}^{\mathrm{j}\omega}) = \frac{1}{2}W_R(\mathrm{e}^{\mathrm{j}\omega}) - \frac{1}{4}W_R(\mathrm{e}^{\mathrm{j}(\omega-\frac{2\pi}{M})}) + \frac{1}{4}W_R(\mathrm{e}^{\mathrm{j}(\omega+\frac{2\pi}{M})})$$

(b) Comments:
The second and third terms widen the mainlobe of Hann window and the sidelobes are lowed by the scaling factor.

28. (a) See plot below.

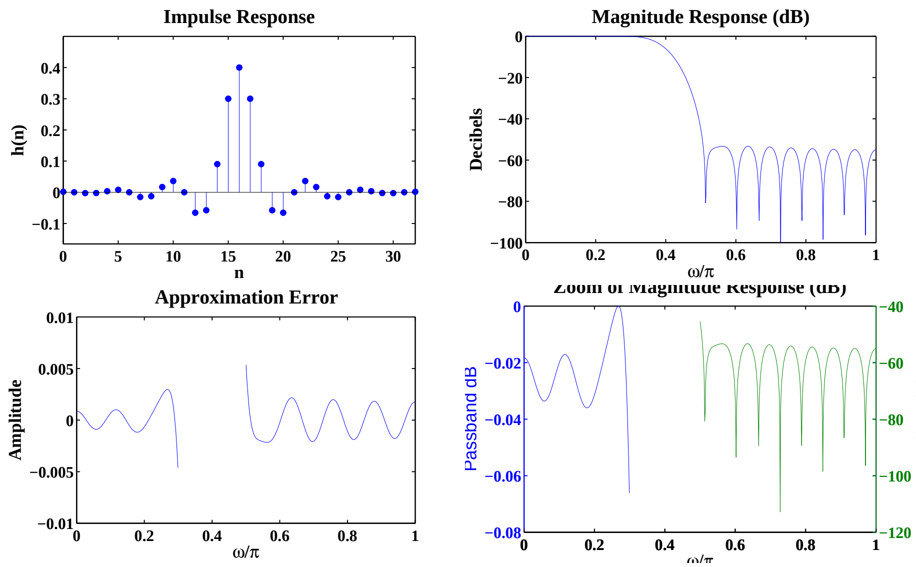

FIGURE 10.34: Plots of impulse response, magnitude response, approximation error and zoom magnitude plot using fixed window design technique.

(b) See plot below.

MATLAB script:

```
% P1028: Design lowpass filter using appropriate window
close all; clc
ws = 0.5*pi; wp = 0.3*pi;
As = 50; Ap = 0.5;
[deltap, deltas] = spec_convert(Ap,As,'rel','abs');
delta = min([deltap,deltas]);
A = -20*log10(delta);

%% Part (a)
wc = (ws+wp)/2;
dw = ws - wp;
L = 6.6*pi/dw;
M = L-1;
if mod(M,2) == 1
    M = M+1;
end
```

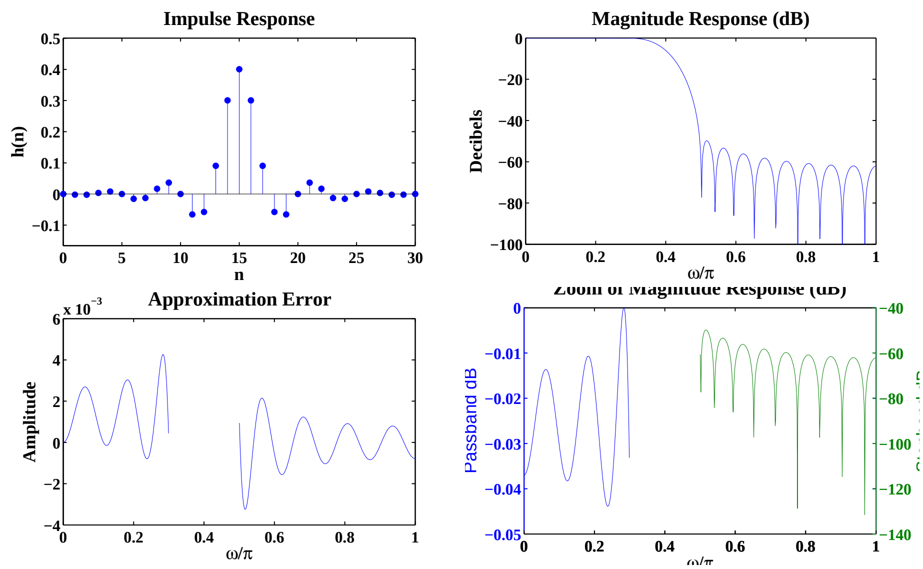

FIGURE 10.35: Plots of impulse response, magnitude response, approximation error and zoom magnitude plot using Kaiser window design technique.

```
hd = ideallp(wc,M);
h = hd.*hamming(M+1);

%% Part (b)
% [M,wn,beta,ftype] = kaiserord([0.3 0.5],[1 0],[deltas,deltap]);
% h = fir1(M,wn,ftype,kaiser(M+1,beta));

w = linspace(0,1,1000)*pi;
H = freqz(h,1,w);
Hmag = abs(H);
Hdb = 20*log10(Hmag./max(Hmag));
[Ha w2 P2 L2] = amplresp(h(:)',w);
aperr = nan(1,length(w));
magz1 = nan(1,length(w));
magz2 = nan(1,length(w));
ind = w <= wp;
aperr(ind) = Ha(ind) - 1;
magz1(ind) = Hdb(ind);
ind = w >= ws;
aperr(ind) = Ha(ind);
```

```
magz2(ind) = Hdb(ind);
%% Plot:
hfa = figconfg('P1028a','small');
stem(0:M,h,'filled');
xlim([0 M])
ylim([min(h)-0.1 max(h)+0.1])
xlabel('n','fontsize',LFS)
ylabel('h(n)','fontsize',LFS)
title('Impulse Response','fontsize',TFS)

hfb = figconfg('P1028b','small');
plot(w/pi,Hdb);
ylim([-100 0])
xlabel('\omega/\pi','fontsize',LFS)
ylabel('Decibels','fontsize',LFS)
title('Magnitude Response (dB)','fontsize',TFS)

hfc = figconfg('P1028c','small');
plot(w/pi,aperr);
xlabel('\omega/\pi','fontsize',LFS)
ylabel('Amplitude','fontsize',LFS)
title('Approximation Error','fontsize',TFS)

hfd = figconfg('P1028d','small');
[AX hf1 hf2] = plotyy(w/pi,magz1,w/pi,magz2);
xlabel('\omega/\pi','fontsize',LFS)
title('Zoom of Magnitude Response (dB)','fontsize',TFS)
set(get(AX(1),'Ylabel'),'string','Passband dB','fontsize',LFS)
set(get(AX(2),'Ylabel'),'string','Stopband dB','fontsize',LFS)
```

29. (a) See plot below.

    (b) See plot below.

MATLAB script:

```
% P1029: Design bandstop filter using hann window
close all; clc
wp1 = 0.2*pi; ws1 = 0.3*pi; ws2 = 0.5*pi; wp2 = 0.65*pi;
deltas = 0.01; deltap = 0.056;
delta = min([deltap,deltas]);
```