5.43 Repeat Problem 5.42 for the linear time-invariant discrete-time system with frequency response function

$$H(\Omega) = \frac{0.04}{e^{j2\Omega} - 1.6e^{j\Omega} + 0.64}$$

****

(a) The input $x[n] = u[n] - u[n-10]$ is applied to the filter.

(i) Using `fft` in MATLAB, compute the 32-point DFT of the resulting output response. *Note:* To calculate the DFT of the output, Y_k, write an M-file that carries out the multiplication of the DFT of the input, X_k, with $H(2\pi k/N)$, where $H(\Omega)$ is the frequency response function of the filter. Take $N = 32$.

(ii) Using `ifft` in MATLAB, compute the output response $y[n]$ for $n = 0, 1, 2, \ldots, 31$.

(b) Repeat part (a) for the input $x[n] = u[n] - u[n-5]$.

(c) Compare the output response obtained in parts (a) and (b). In what respects do the responses differ? Explain.

- Plot both $x[n]$ & $y[n]$. In addition, plot the magnitude and phase (deg) of X_k, H_k, and Y_k. Hint: remember H_k corresponds to $H(\Omega)$ for $0 \le \Omega < 2\pi$, i.e., $H_k = H(\Omega_k = 2\pi k/N)$.

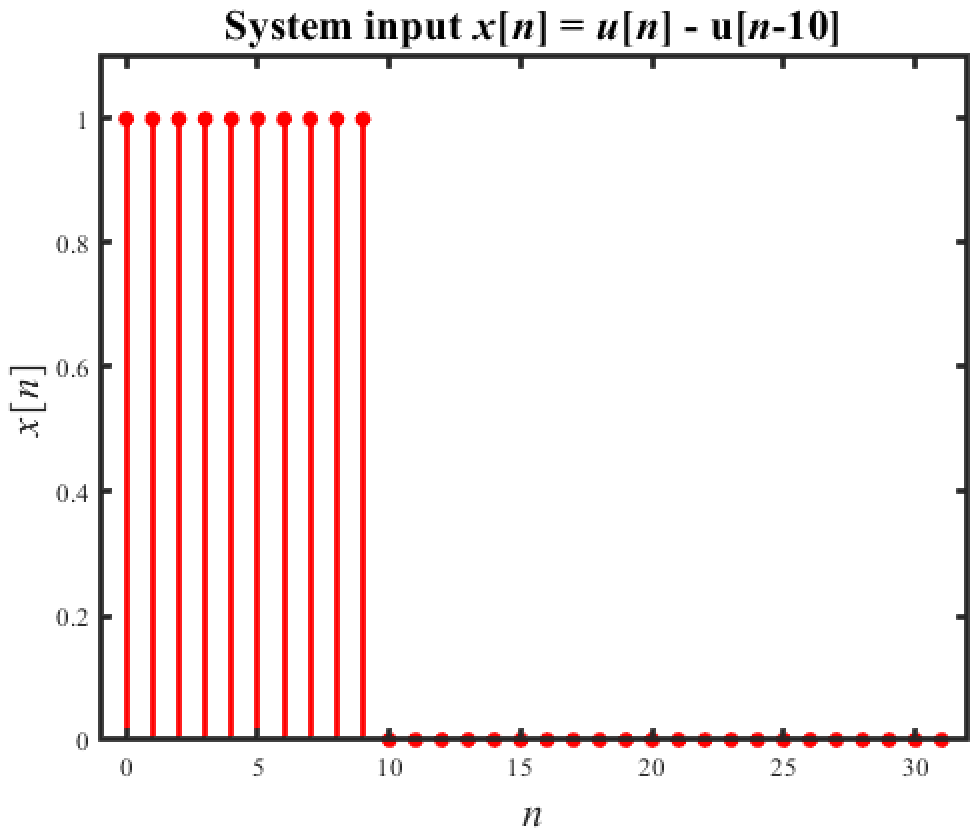
a)

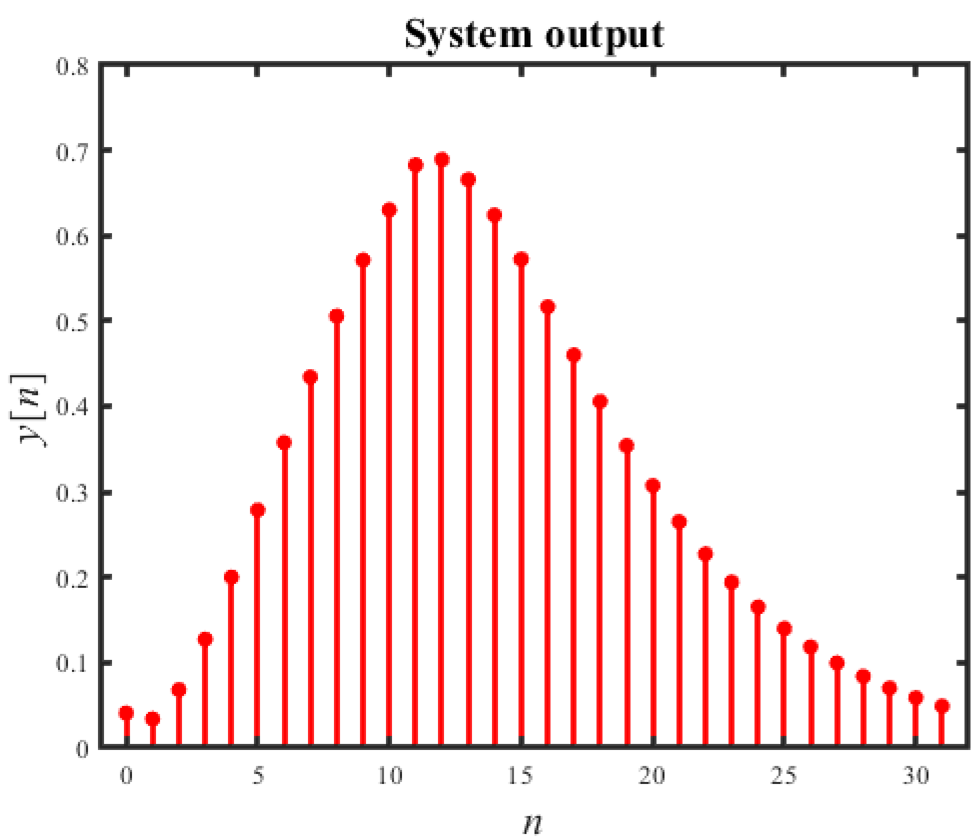
```
% Chapter 5 problem 5.43a (chap5_5_43a.m)
% EE 313 your name, mm/dd/yyy
% Plot system input x[n] = u[n] - u[n-10] and output y[n] when
% the DTFT frequency response of the system is
%          H(W) = 0.04/(e^{j2W} - 1.6*e^{jW} + 0.64)
% using 32-point FFT and IFFT.  Also, plot the magnitude
% and phase (rad) of Xk, Hk, and Yk.
clear; clc; close all;
L = 32; n = 0:1:L-1; x = [ones(1,10),zeros(1,L-10)];
Omega = 2*pi*n/L;
Hk = 0.04./(exp(j*2*Omega) - 1.6*exp(j*Omega) + 0.64);
Xk = fft(x,L); Yk = Xk.*Hk; y = real(ifft(Yk));
% Plot system input x[n]
stem(n,x,'r.','linewidth',2,'markersize',20), axis([-1 L 0 1.1]),
xlabel('\itn','fontsize',16,'fontname','times'),
ylabel('{\itx}[{\itn}]','fontsize',16,'fontname','times'),
title('System input {\itx}[{\itn}] = {\itu}[{\itn}] - u[{\itn}-10]',...
    'fontsize',16,'fontname','times'),
% Plot system output y[n]
figure, stem(n,y,'r.','linewidth',2,'markersize',20),
axis([-1 L 0 0.8]),
xlabel('\itn','fontsize',16,'fontname','times'),
ylabel('{\ity}[{\itn}]','fontsize',16,'fontname','times'),
title('System output','fontsize',16,'fontname','times'),
% Plot system input DFT Xk
figure, stem(n,abs(Xk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 11]),
```

a) continued

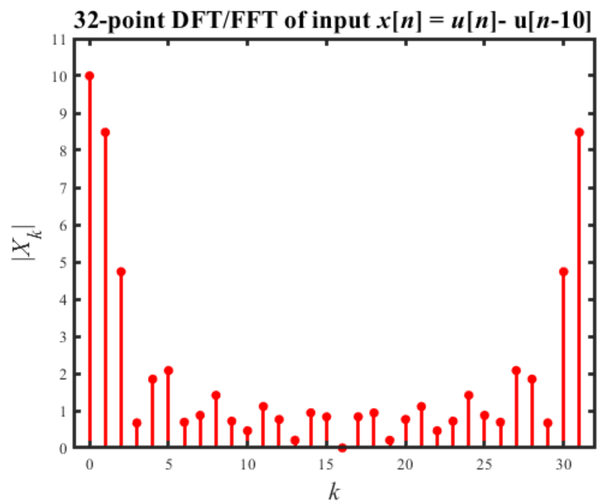
```
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itX_k}|','fontsize',16,'fontname','times'),

title(['32-point DFT/FFT of input {\itx}[{\itn}] = {\itu}[{\itn}]',...
    '- u[{\itn}-10]'],'fontsize',16,'fontname','times'),
figure, stem(n,angle(Xk),'r.','linewidth',2,'markersize',20),
axis([-1 L -pi pi]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itX_k} (rad)','fontsize',16,'fontname','times'),
title(['32-point DFT/FFT of input {\itx}[{\itn}] = {\itu}[{\itn}]',...
    '- u[{\itn}-10]'],'fontsize',16,'fontname','times'),
% Plot system frequency response Hk
figure, stem(n,abs(Hk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 1.1]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itH_k}|','fontsize',16,'fontname','times'),
title({'System frequency response';['{\itH}(\Omega = 2\pik/32) ',...
    '= 0.04 / ({\ite}^{j2\Omega} - 1.6{\ite}^{j\Omega} + 0.64)']},...
    'fontsize',16,'fontname','times'),
figure, stem(n,angle(Hk),'r.','linewidth',2,'markersize',20),
axis([-1 L -pi pi]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itH_k} (rad)','fontsize',16,'fontname','times'),
title({'System frequency response';['{\itH}(\Omega = 2\pik/32) ',...
    '= 0.04 / ({\ite}^{j2\Omega} - 1.6{\ite}^{j\Omega} + 0.64)']},...
    'fontsize',16,'fontname','times'),
% Plot system output DFT Yk
figure, stem(n,abs(Yk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 11]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itY_k}|','fontsize',16,'fontname','times'),
title('32-point DFT/FFT of output {\itY_k} = {\itX_k H_k}',...
    'fontsize',16,'fontname','times'),
figure, stem(n,angle(Yk),'r.','linewidth',2,'markersize',20),
axis([-1 L -pi pi]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itY_k} (rad)','fontsize',16,'fontname','times'),
title('32-point DFT/FFT of system output {\itY_k} = {\itX_k H_k}',...
    'fontsize',16,'fontname','times'),
set(findobj('type','line'),'markersize',18,'fontname','times')
set(findobj('type','axes'),'linewidth',2,'fontname','times')
```

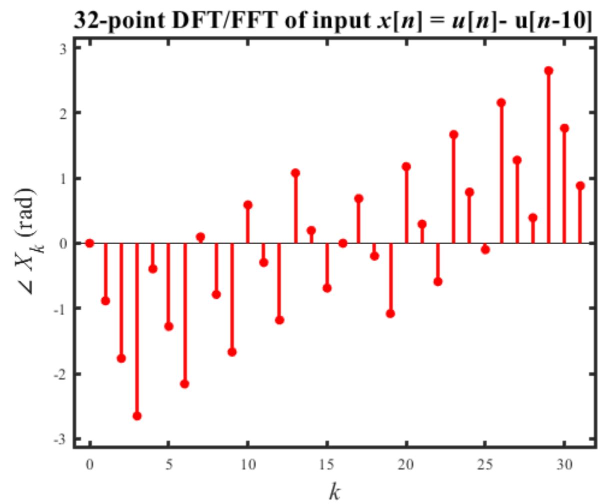
a) continued

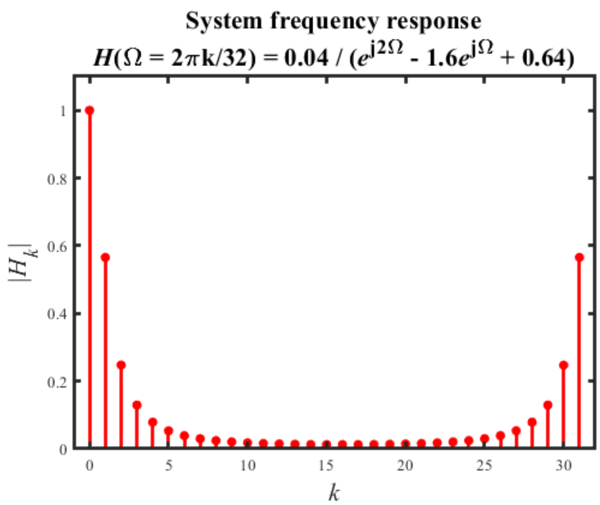

System input x[n] = u[n] - u[n-10]
x[n]
n
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30

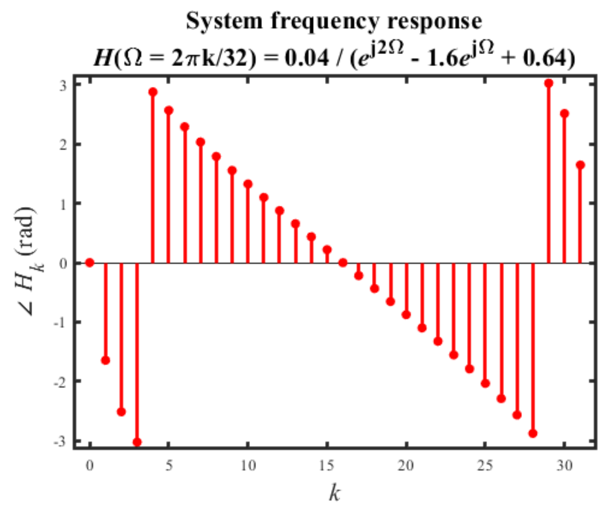

System output
y[n]
n
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30

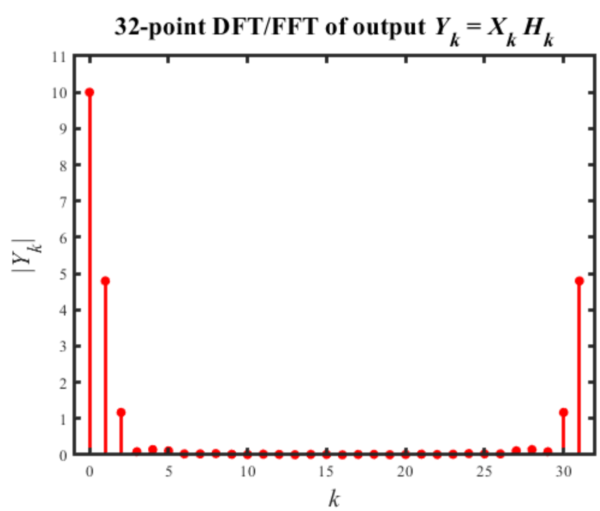
a) continued

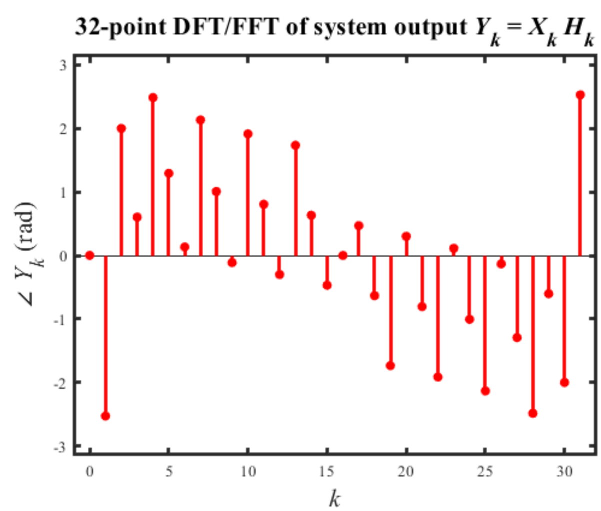












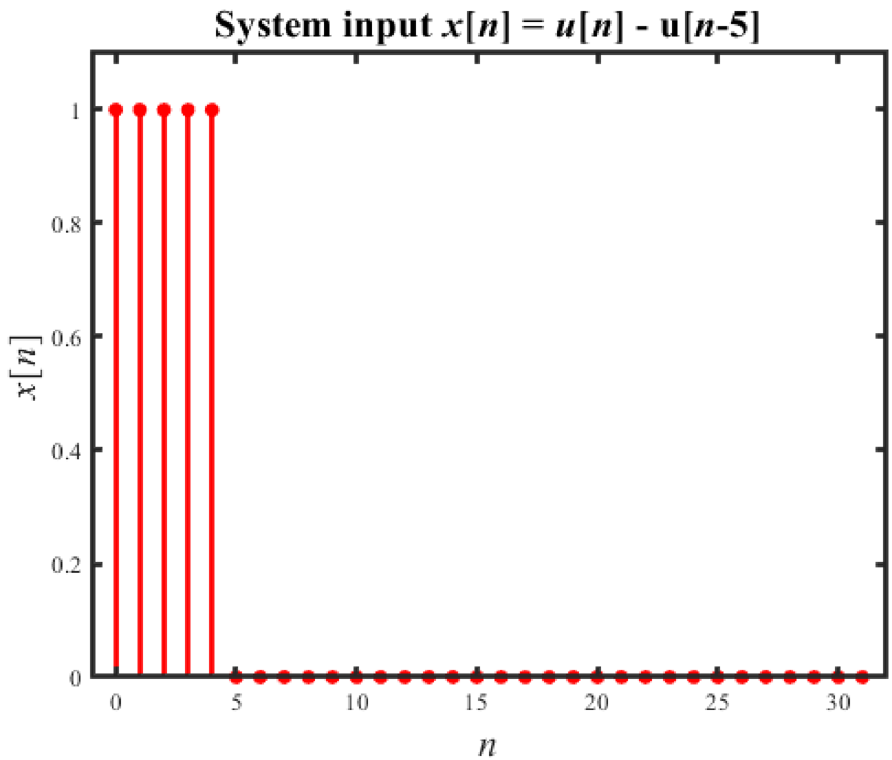
b)

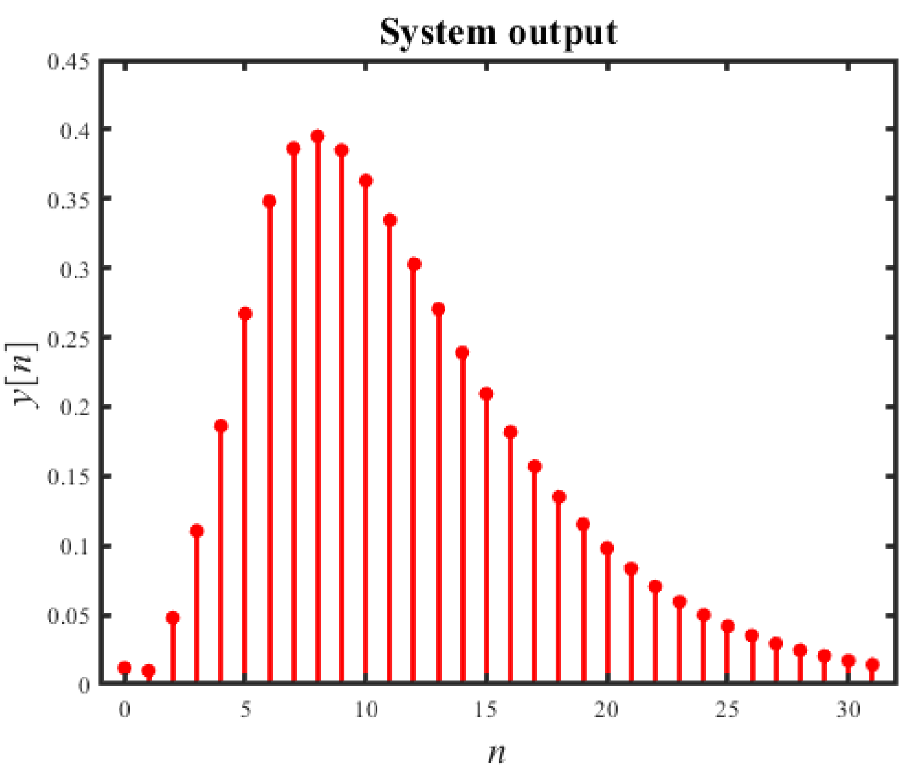
```
% Chapter 5 problem 5.43b (chap5_5_43b.m)
% EE 313 your name, mm/dd/yyy
```

```
% Plot system input x[n] = u[n]-u[n-5] and output y[n] when
% the DTFT frequency response of the system is
%           H(W) = 0.04/(e^{j2W} - 1.6*e^{jW} + 0.64)
% using 32-point FFT and IFFT.  Also, plot the magnitude
% and phase (rad) of Xk, Hk, and Yk.
clear; clc; close all;
L = 32; n = 0:1:L-1; x = [ones(1,5),zeros(1,L-5)];
Omega = 2*pi*n/L;
Hk = 0.04./(exp(j*2*Omega) - 1.6*exp(j*Omega) + 0.64);
Xk = fft(x,L); Yk = Xk.*Hk; y = real(ifft(Yk));
% Plot system input x[n]
stem(n,x,'r.','linewidth',2,'markersize',20), axis([-1 L 0 1.1]),
xlabel('\itn','fontsize',16,'fontname','times'),
ylabel('{\itx}[{\itn}]','fontsize',16,'fontname','times'),
title('System input {\itx}[{\itn}] = {\itu}[{\itn}] - u[{\itn}-5]',...
    'fontsize',16,'fontname','times'),
% Plot system output y[n]
figure, stem(n,y,'r.','linewidth',2,'markersize',20),axis([-1 L 0 0.45]),
xlabel('\itn','fontsize',16,'fontname','times'),
ylabel('{\ity}[{\itn}]','fontsize',16,'fontname','times'),
title('System output','fontsize',16,'fontname','times'),
% Plot system input DFT Xk
figure, stem(n,abs(Xk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 5.5]), xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itX_k}|','fontsize',16,'fontname','times'),
title(['32-point DFT/FFT of input {\itx}[{\itn}] = {\itu}[{\itn}]',...
    '- u[{\itn}-5]'],'fontsize',16,'fontname','times'),
figure, stem(n,angle(Xk),'r.','linewidth',2,'markersize',20),
axis([-1 L -pi pi]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itX_k} (rad)','fontsize',16,'fontname','times'),
title(['32-point DFT/FFT of input {\itx}[{\itn}] = {\itu}[{\itn}]',...
    '- u[{\itn}-5]'],'fontsize',16,'fontname','times'),
% Plot system frequency response Hk
figure, stem(n,abs(Hk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 1.1]), xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itH_k}|','fontsize',16,'fontname','times'),
title({'System frequency response';['{\itH}(\Omega = 2\pik/32) ',...
    '= 0.04 / ({\ite}^{j2\Omega} - 1.6{\ite}^{j\Omega} + 0.64)']},...
    'fontsize',16,'fontname','times'),
figure, stem(n,angle(Hk),'r.','linewidth',2,'markersize',20),
axis([-1 L -pi pi]), xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itH_k} (rad)','fontsize',16,'fontname','times'),
title({'System frequency response';['{\itH}(\Omega = 2\pik/32) ',...
    '= 0.04 / ({\ite}^{j2\Omega} - 1.6{\ite}^{j\Omega} + 0.64)']},...
    'fontsize',16,'fontname','times'),
% Plot system output DFT Yk
figure, stem(n,abs(Yk),'r.','linewidth',2,'markersize',20),
axis([-1 L 0 5.5]),
xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('|{\itY_k}|','fontsize',16,'fontname','times'),

title('32-point DFT/FFT of output {\itY_k} = {\itX_k H_k}',...
    'fontsize',16,'fontname','times'),
figure, stem(n,angle(Yk),'r.','linewidth',2,'markersize',20),
```

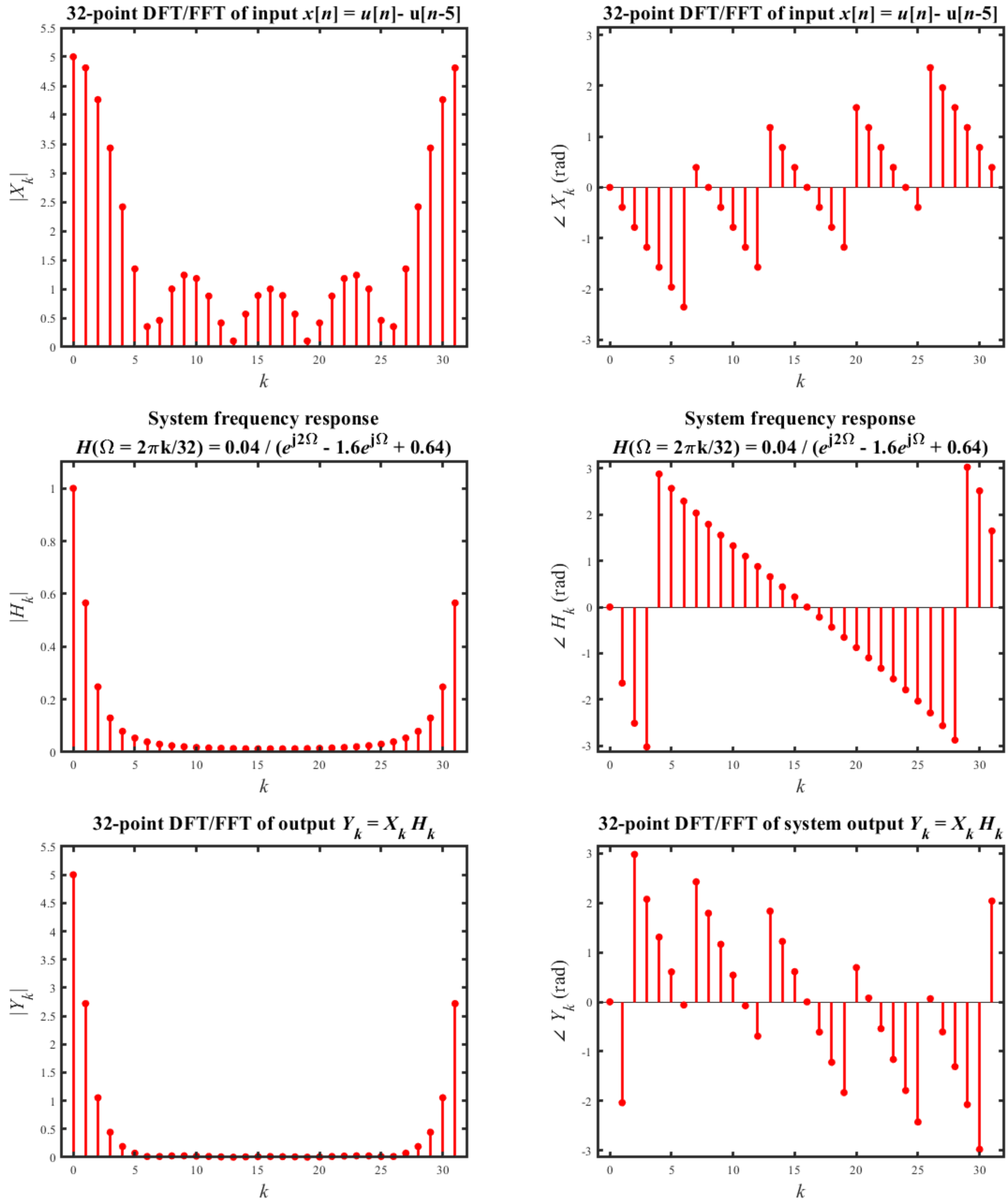
b) cont.

```
axis([-1 L -pi pi]), xlabel('\itk','fontsize',16,'fontname','times'),
ylabel('\angle {\itY_k} (rad)','fontsize',16,'fontname','times'),
title('32-point DFT/FFT of system output {\itY_k} = {\itX_k H_k}',...
    'fontsize',16,'fontname','times'),
set(findobj('type','line'),'markersize',18,'fontname','times')
set(findobj('type','axes'),'linewidth',2,'fontname','times')
```





b) continued



c) From the H_k plots, we see that the system passes lower frequencies and has a nearly linear phase which corresponds to a time-delay. The part a) input, a longer rectangular pulse w/ more low frequency content, is less affected by the LP filter than the shorter part b) rectangular pulse w/ more high frequency content.