ECG680 Computer Lab #4

2020/11/10

Minsung Cho

1. Resonator

a) Determine a LCCDE which has an impulse response of

$$h[n] = r^n cos(\omega_0 n)u[n]$$

where $\omega_0 = \pi/10$.

Answer:

$$y = (n) = x(n) - rcos(\pi/10)x(n-1) + 2cos(\pi/10)y(n-1) - y(n-2).$$

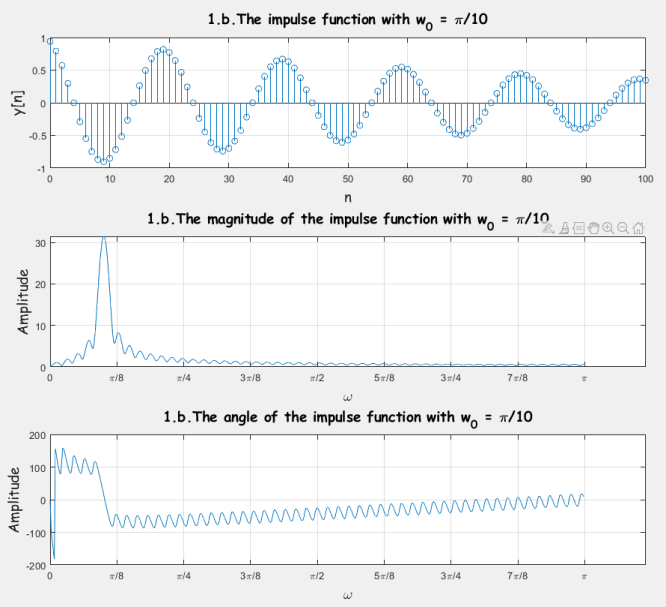
b) Using MATLAB's freqz function, plot magnitude of the frequency response for this system when r=0.99.

Code:

```
clearvars
r = 0.99;
w0 = pi/10;
for n = 1:101
   y1(n) = r^n*cos(w0*n);
end

n1 = [0:length(y1)-1];

figure(1)
subplot(3,1,1)
stem(n1,y1)
grid on
title('1.b.The impulse function with w_0 = \pi/10', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h1, w1] = freqz(y1, 1, 512);
mag1 = abs(h1);
rad2deg = 180/pi;
ang_h1 = wrapTo180(unwrap(angle(h1))*rad2deg);

subplot(3,1,2)
plot(w1,mag1)
grid on
title('1.b.The magnitude of the impulse function with w_0 = \pi/10', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w1,ang_h1)
grid on
title('1.b.The angle of the impulse function with w_0 = \pi/10', 'fontname', 'Comic Sans MS', 'fontsize',
14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

Plots:



c) Write a MATLAB script to implement your LCCDE. Using this script, plot the first 101 samples of the filter's impulse response for

i) r=0.99

see 1.b

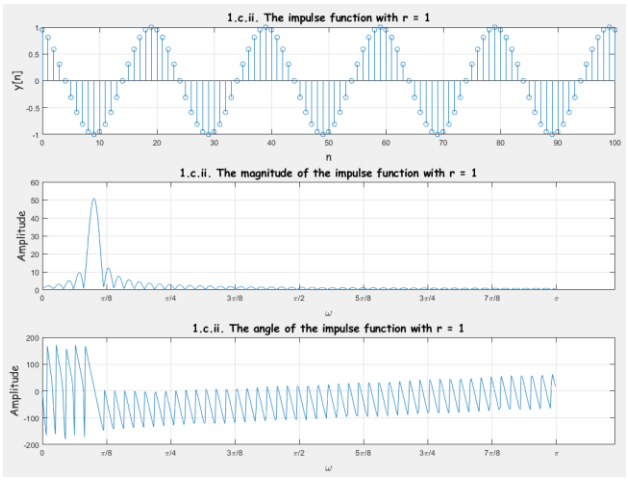
ii) r=1

code:

```
clearvars
r = 1;
w0 = pi/10;
for n = 1:101
   y2(n) = r^n*cos(w0*n);
```

```
end

n2 = [0:length(y2)-1];

figure(2)
subplot(3,1,1)
stem(n2,y2)
grid on
title('1.c.ii. The impulse function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h2, w2] = freqz(y2, 1, 512);
mag2 = abs(h2);
rad2deg = 180/pi;
ang_h2 = wrapTo180(unwrap(angle(h2))*rad2deg);

subplot(3,1,2)
plot(w2,mag2)
grid on
title('1.c.ii. The magnitude of the impulse function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w2,ang_h2)
grid on
title('1.c.ii. The angle of the impulse function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



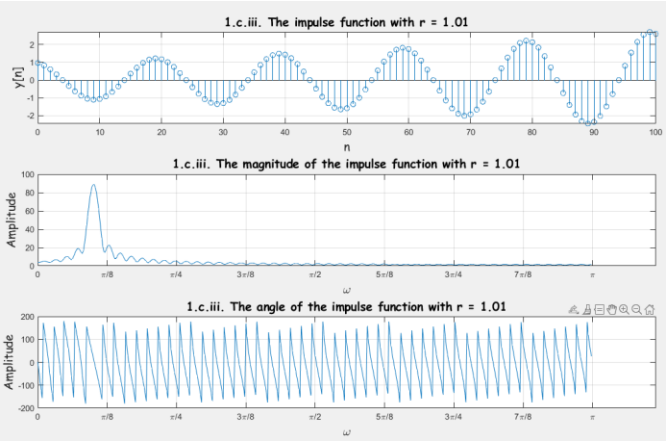
iii) r=1.01

code:

```
clearvars
r = 1.01;
w0 = pi/10;
for n = 1:101
   y3(n) = r^n*cos(w0*n);
end

n3 = [0:length(y3)-1];

figure(3)
subplot(3,1,1)
stem(n3,y3)
grid on
title('1.c.iii. The impulse function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h3, w3] = freqz(y3, 1, 512);
mag3 = abs(h3);
rad2deg = 180/pi;
ang_h3 = wrapTo180(unwrap(angle(h3))*rad2deg);

subplot(3,1,2)
plot(w3,mag3)
grid on
title('1.c.iii. The magnitude of the impulse function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize',
14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
```

```
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w3,ang_h3)
grid on
title('1.c.iii. The angle of the impulse function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



d) Using your script from part c) of this exercise, calculate the first 251 samples of the zero state response (ZSR) of your difference equation when the input, x[n] is $x[n]=\cos(\omega_0 n)u[n]$ where $\omega_0 = \pi/10$ and

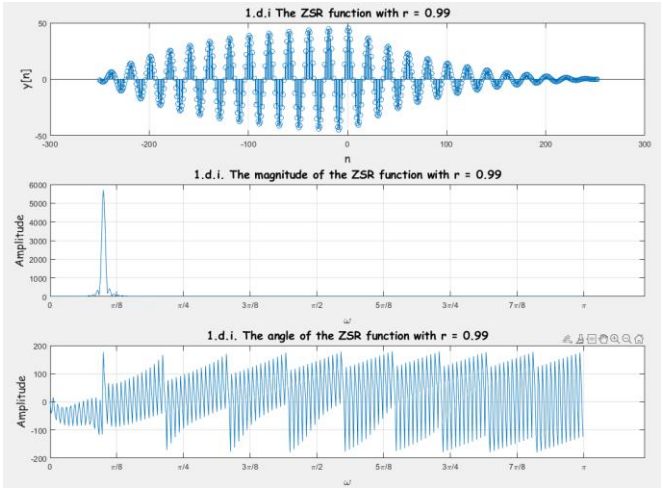
i) r=0.99

code:

```
clearvars
r = 0.99;
w0 = pi/10;
for n = 1:252
   h(n) = r^n*cos(w0*n);
   x(n) = cos(w0*n);
end
nh = [1:252];
nx = nh;
[y4, n4] = convolve(h, nh, x, nx);

figure(4)
subplot(3,1,1)
stem(n4,y4)
```

```
grid on
title('1.d.i The ZSR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h4, w4] = freqz(y4, 1, 512);
mag4 = abs(h4);
rad2deg = 180/pi;
ang_h4 = wrapTo180(unwrap(angle(h4))*rad2deg);

subplot(3,1,2)
plot(w4,mag4)
grid on
title('1.d.i. The magnitude of the ZSR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w4,ang_h4)
grid on
title('1.d.i. The angle of the ZSR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



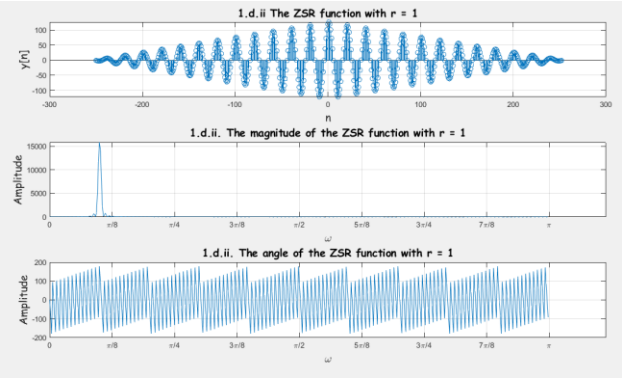
ii) r=1

code:

```
clearvars
```

```
r = 1;
w0 = pi/10;
for n = 1:252
   h1(n) = r^n*cos(w0*n);
   x1(n) = cos(w0*n);
end
nh1 = [1:252];
nx1 = nh1;
[y5, n5] = convolve(h1, nh1, x1, nx1);

figure(5)
subplot(3,1,1)
stem(n5,y5)
grid on
title('1.d.ii The ZSR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h5, w5] = freqz(y5, 1, 512);
mag5 = abs(h5);
rad2deg = 180/pi;
ang_h5 = wrapTo180(unwrap(angle(h5))*rad2deg);

subplot(3,1,2)
plot(w5,mag5)
grid on
title('1.d.ii. The magnitude of the ZSR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})


subplot(3,1,3)

plot(w5,ang_h5)

grid on

title('1.d.ii. The angle of the ZSR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)

xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)

ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)

xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])

xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

Plots:



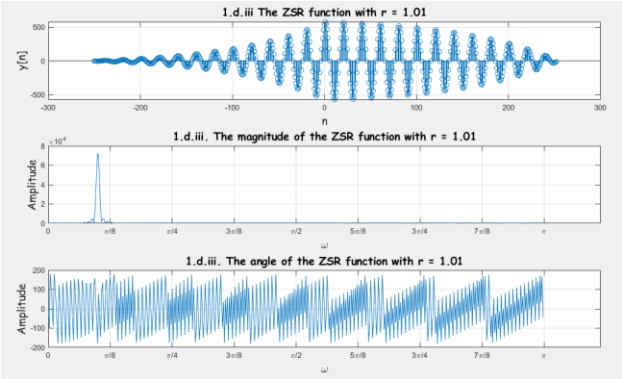
iii) r=1.01

code:

```
clearvars
r = 1.01;
w0 = pi/10;
for n = 1:252
   h2(n) = r^n*cos(w0*n);
   x2(n) = cos(w0*n);
end
nh2 = [1:252];
nx2 = nh2;
[y6, n6] = convolve(h2, nh2, x2, nx2);

figure(6)
subplot(3,1,1)
stem(n6,y6)
grid on
title('1.d.iii The ZSR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h6, w6] = freqz(y6, 1, 512);
mag6 = abs(h6);
rad2deg = 180/pi;
ang_h6 = wrapTo180(unwrap(angle(h6))*rad2deg);

subplot(3,1,2)
plot(w6,mag6)
grid on
title('1.d.iii. The magnitude of the ZSR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
```

```
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w6,ang_h6)
grid on
title('1.d.iii. The angle of the ZSR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



e) Using your script from part c) of this exercise, calculate the first 251 samples of the zero input response(ZIR) of your difference equation when y[-1]=4, y[-2]=4 and

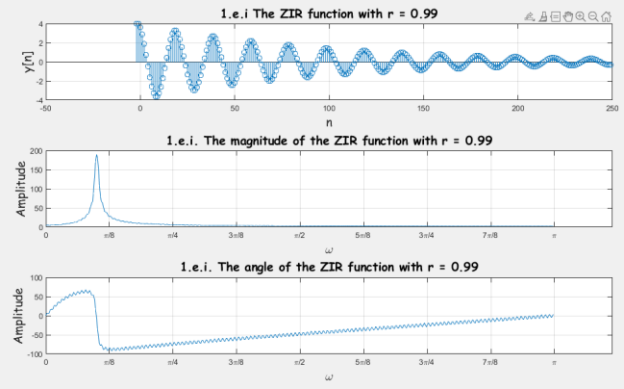
i) r=0.99

code:

```
clearvars
r = 0.99;
w0 = pi/10;

x = zeros(1,252);
y7 = zeros(1,252);
y7(1,1) = 4;
y7(1,2) = 4;

for n = 0:249
   y7(1,n+3) = x(1,n+3)-r.*cos(w0).*x(1,n+2)+2.*r.*cos(w0).*y7(1,n+2)-r.^2.*y7(1,n+1);
end
n7 = [-2:249];

figure(7)
subplot(3,1,1)
```

```
stem(n7,y7)
grid on
title('1.e.i The ZIR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h7, w7] = freqz(y7, 1, 512);
mag7 = abs(h7);
rad2deg = 180/pi;
ang_h7 = wrapTo180(unwrap(angle(h7))*rad2deg);

subplot(3,1,2)
plot(w7,mag7)
grid on
title('1.e.i. The magnitude of the ZIR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w7,ang_h7)
grid on
title('1.e.i. The angle of the ZIR function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



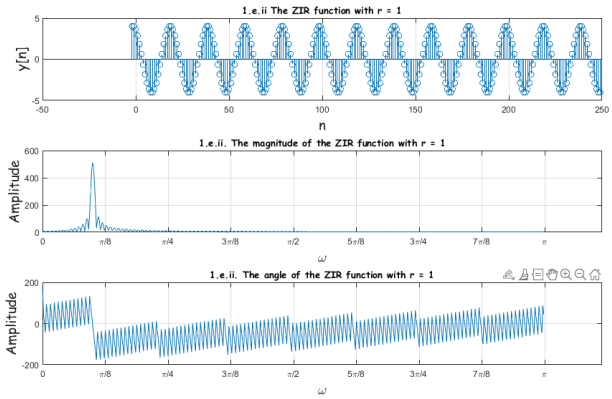
ii) r=1

code:

```
clearvars
r = 1;
w0 = pi/10;
```

```
x = zeros(1,252);
y8 = zeros(1,252);
y8(1,1) = 4;
y8(1,2) = 4;

for n = 0:249
   y8(1,n+3) = x(1,n+3)-r.*cos(w0).*x(1,n+2)+2.*r.*cos(w0).*y8(1,n+2)-r.^2.*y8(1,n+1);
end
n8 = [-2:249];

figure(8)
subplot(3,1,1)
stem(n8,y8)
grid on
title('1.e.ii The ZIR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h8, w8] = freqz(y8, 1, 512);
mag8 = abs(h8);
rad2deg = 180/pi;
ang_h8 = wrapTo180(unwrap(angle(h8))*rad2deg);

subplot(3,1,2)
plot(w8,mag8)
grid on
title('1.e.ii. The magnitude of the ZIR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w8,ang_h8)
grid on
title('1.e.ii. The angle of the ZIR function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



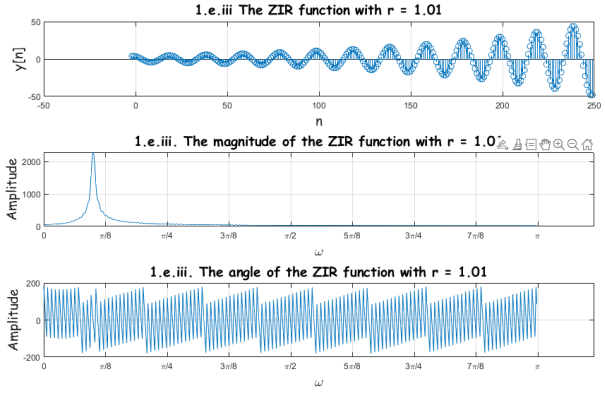
iii) r=1.1

code:

```
clearvars
r = 1.01;
w0 = pi/10;

x = zeros(1,252);
y9 = zeros(1,252);
y9(1,1) = 4;
y9(1,2) = 4;

for n = 0:249
   y9(1,n+3) = x(1,n+3)-r.*cos(w0).*x(1,n+2)+2.*r.*cos(w0).*y9(1,n+2)-r.^2.*y9(1,n+1);
end
n9 = [-2:249];

figure(9)
subplot(3,1,1)
stem(n9,y9)
grid on
title('1.e.iii The ZIR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h9, w9] = freqz(y9, 1, 512);
mag9 = abs(h9);
rad2deg = 180/pi;
ang_h9 = wrapTo180(unwrap(angle(h9))*rad2deg);

subplot(3,1,2)
plot(w9,mag9)
grid on
title('1.e.iii. The magnitude of the ZIR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w9,ang_h9)
grid on
title('1.e.iii. The angle of the ZIR function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



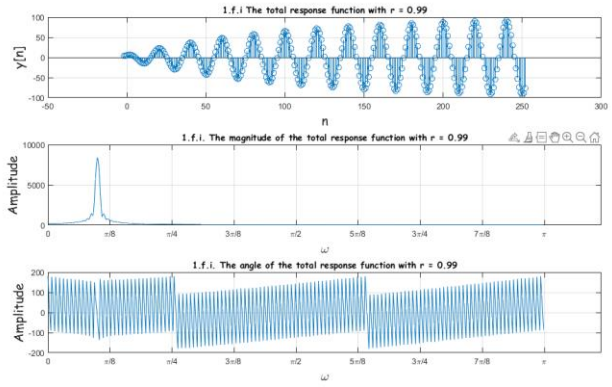
f) Using your script from part c) of this exercise, find the total response of your difference equation when y[-1]=4, y[-2]=4, the input, x[n], is $x[n]=\cos(\omega_0 n)u[n]$ where $\omega_0 = \pi/10$ and

i) r=0.99

code:

```
clearvars
r = 0.99;
w0 = pi/10;

x = zeros(1,252);

for i = 0:252
x(1,i+3) = cos(w0.*i);
end

yzir = zeros(1,252);
yzir(1,1) = 4;
yzir(1,2) = 4;

for i = 0:252
```

```
yzir(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzir(1,i+2) - r.^2.*yzir(1,i+1);
end

yzsr = zeros(1,252);

for i = 0:252
yzsr(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzsr(1,i+2) - r.^2.*yzsr(1,i+1);
end

ytot = yzsr+yzir;
n = [-2:252];

figure(10)
subplot(3,1,1)
stem(n,ytot)
grid on
title('1.f.i The total response function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(ytot, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
title('1.f.i. The magnitude of the total response function with r = 0.99', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('1.f.i. The angle of the total response function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize',
14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})


plots:
```



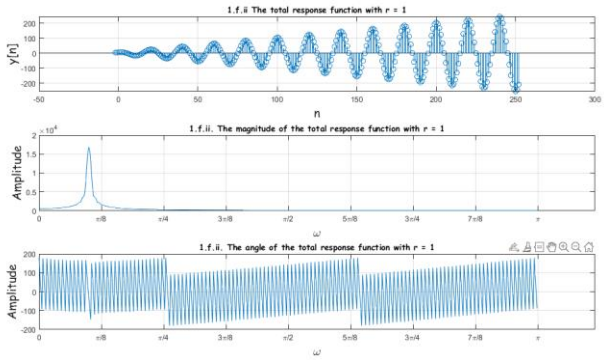
ii) r=1

code:

```
clearvars
r = 1;
w0 = pi/10;

x = zeros(1,252);

for i = 0:252
x(1,i+3) = cos(w0.*i);
end

yzir = zeros(1,252);
yzir(1,1) = 4;
yzir(1,2) = 4;

for i = 0:252
yzir(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzir(1,i+2) - r.^2.*yzir(1,i+1);
end

yzsr = zeros(1,252);

for i = 0:252
yzsr(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzsr(1,i+2) - r.^2.*yzsr(1,i+1);
end

ytot = yzsr+yzir;
n = [-2:252];

figure(10)
subplot(3,1,1)
stem(n,ytot)
grid on
title('1.f.ii The total response function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(ytot, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
title('1.f.ii. The magnitude of the total response function with r = 1', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('1.f.ii. The angle of the total response function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize',
14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



iii) r=1.01

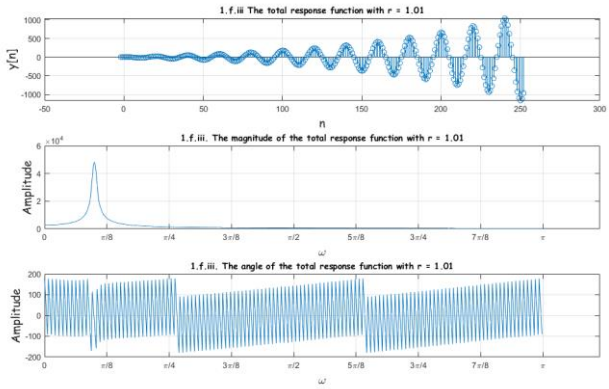
code:

```
clearvars
r = 1.01;
w0 = pi/10;
```

```
x = zeros(1,252);

for i = 0:252
x(1,i+3) = cos(w0.*i);
end

yzir = zeros(1,252);
yzir(1,1) = 4;
yzir(1,2) = 4;

for i = 0:252
yzir(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzir(1,i+2) - r.^2.*yzir(1,i+1);
end

yzsr = zeros(1,252);

for i = 0:252
yzsr(1,i+3) = x(1,i+3) - r.*cos(w0).*x(1,i+2) + 2.*r.*cos(w0).*yzsr(1,i+2) - r.^2.*yzsr(1,i+1);
end

ytot = yzsr+yzir;
n = [-2:252];

figure(11)
subplot(3,1,1)
stem(n,ytot)
grid on
title('1.f.iii The total response function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(ytot, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
title('1.f.iii. The magnitude of the total response function with r = 1.01', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
```

```
grid on
title('1.f.iii. The angle of the total response function with r = 1.01', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



Add your results from parts d) and e) and compare them to your result in part f). Comment on your consumption.

Upon comparing the graph from d), we see that the shape of the function for the ZIR is bounded where the shape of the function for the total response is not, due to the addition of the ZSR function.

Upon comparing the graph from e), we see that the shape of the function is the same but the amplitude of the function is changed.

g) Using MATLAB's filter function, repeat part d) of this exercise.

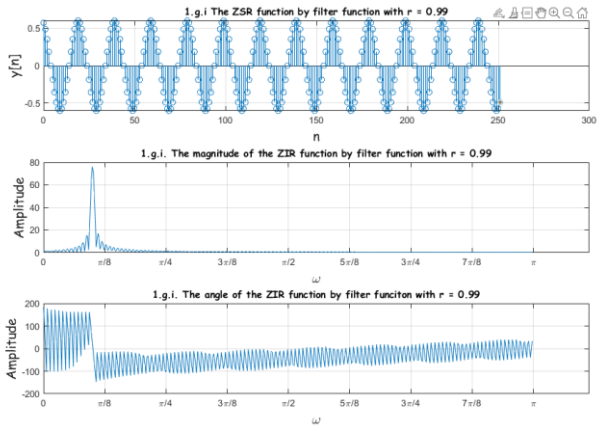
i)

Code:

```
clearvars
r = 0.99;
w0 = pi/10;

for i = 1:252
   x(i) = cos(w0.*i);
end

num = [1-1*r*cos(w0)];
denom = [1-2*r*cos(w0)+r.^2];

y = filter(num, denom,x);
```

```
n = [0:251];

figure(12)
subplot(3,1,1)
stem(n,y)
grid on
title('1.g.i The ZSR function by filter function with r = 0.99', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(y, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
title('1.g.i. The magnitude of the ZIR function by filter function with r = 0.99', 'fontname', 'Comic Sans
MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('1.g.i. The angle of the ZIR function by filter funciton with r = 0.99', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



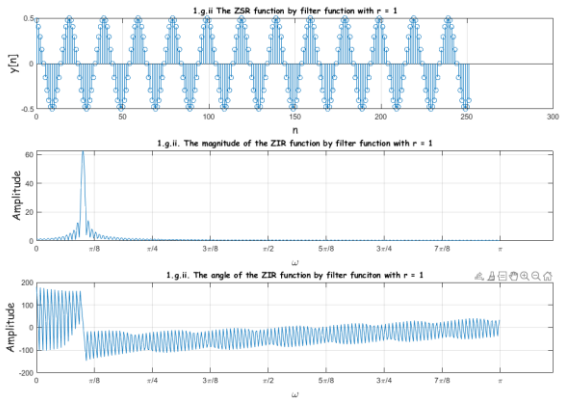
ii)

code:

```
clearvars
r = 1;
w0 = pi/10;

for i = 1:252
   x(i) = cos(w0.*i);
end

num = [1-1*r*cos(w0)];
denom = [1-2*r*cos(w0)+r.^2];

y = filter(num, denom,x);
n = [0:251];

figure(12)
subplot(3,1,1)
stem(n,y)
grid on
title('1.g.ii The ZSR function by filter function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(y, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
```

```
title('1.g.ii. The magnitude of the ZIR function by filter function with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('1.g.ii. The angle of the ZIR function by filter funciton with r = 1', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plot:



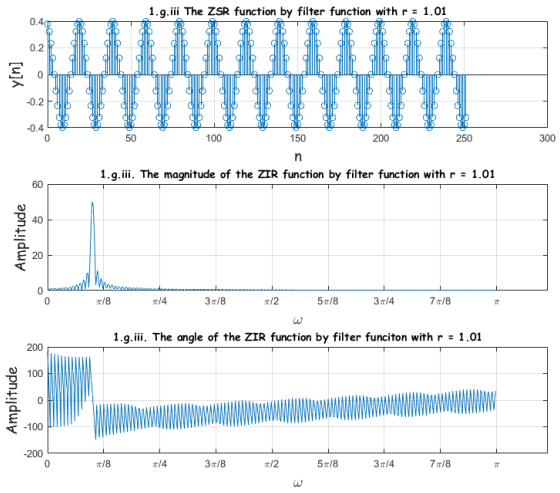
iii)

code:

```
clearvars
r = 1.01;
w0 = pi/10;

for i = 1:252
   x(i) = cos(w0.*i);
end

num = [1-1*r*cos(w0)];
denom = [1-2*r*cos(w0)+r.^2];

y = filter(num, denom,x);
n = [0:251];
```

```
subplot(3,1,1)
stem(n,y)
grid on
title('1.g.iii The ZSR function by filter function with r = 1.01', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

[h, w] = freqz(y, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

subplot(3,1,2)
plot(w,mag)
grid on
title('1.g.iii. The magnitude of the ZIR function by filter function with r = 1.01', 'fontname', 'Comic Sans
MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('1.g.iii. The angle of the ZIR function by filter funciton with r = 1.01', 'fontname', 'Comic Sans MS',
'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



2. IIR Frequency Selective Filters

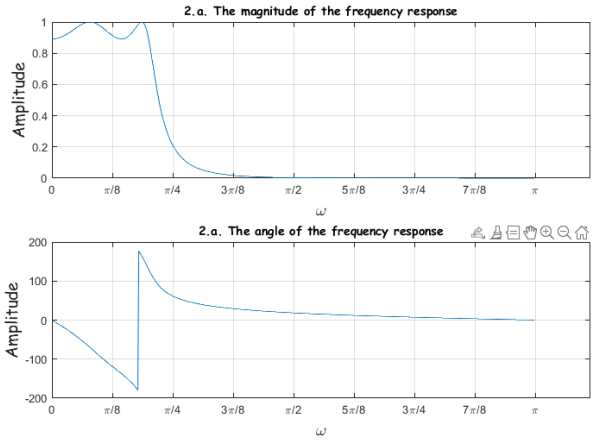
a) Using MATLAB's freqz function, plot the frequency response of this system.

Code:

```
clearvars
b0 = 0.00183555;
b1 = [1 1];
b2 = [1 1];
b3 = [1 1];
b4 = [1 1];
b = b0*conv(conv(conv(b3,b4),b2),b1);
a = [1 -3.05434 3.8289993445 -2.29245273626 0.550744355605];

[h, w] = freqz(b, a, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

figure(14)
subplot(2,1,1)
plot(w,mag)
grid on
title('2.a. The magnitude of the frequency response', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(2,1,2)
plot(w,ang_h)
grid on
title('2.a. The angle of the frequency response', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



b) Using MATLAB's roots function, determine the poles of this system. Using either MATLAB or a hand sketch, make a pole zero plot of H(z). Assuming that the system is causal, what can you say about the filter's stability and why?

Poles:

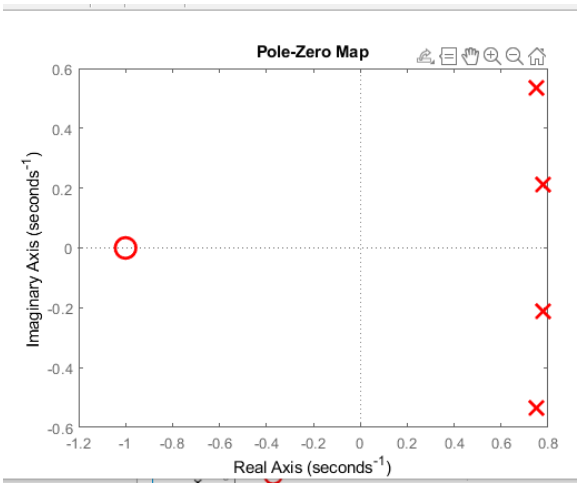
	1
1	0.7498 + 0.5348i
2	0.7498 - 0.5348i
3	0.7774 + 0.2120i
4	0.7774 - 0.2120i

Code:

```
clearvars
b0 = 0.00183555;
b1 = [1 1];
b2 = [1 1];
b3 = [1 1];
b4 = [1 1];
b = b0*conv(conv(conv(b3,b4),b2),b1);
a = [1 -3.05434 3.8289993445 -2.29245273626 0.550744355605];

sys = tf(b,a);
figure(15)
pzmap(sys, 'r')
mark = findobj(gca, 'type', 'line');
for i = 1:length(mark)
   set(mark(i), 'markersize', 14);
```

```
   set(mark(i), 'linewidth',2);
end
```

plot:



The ROC is the circular region including all 4 poles.

c) Generate and plot the first 101 samples of the following sequences.

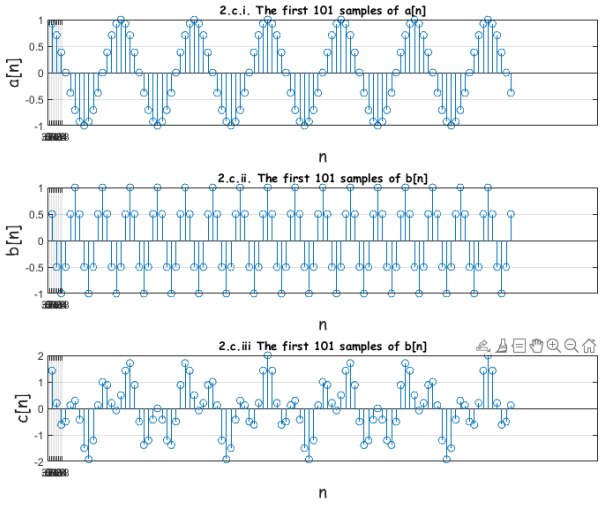
i) a[n]=cos[(π/8)n]u[n] ii) a[n]=cos[(π/3)n]u[n] iii) a[n]=cos[(π/8)n]u[n] + a[n]=cos[(π/3)n]u[n]

code:

```
clearvars
for n = 1:101;
   a(n) = cos(pi/8*n);
   b(n) = cos(pi/3*n);
   c(n) = cos(pi/8*n)+cos(pi/3*n);
end

n = [1:101];
figure(16)
subplot(3,1,1)
stem(n,a)
grid on
title('2.c.i. The first 101 samples of a[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('a[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,2)
stem(n,b)
grid on
title('2.c.ii. The first 101 samples of b[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('b[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
stem(n,c)
grid on
title('2.c.iii The first 101 samples of b[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('c[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



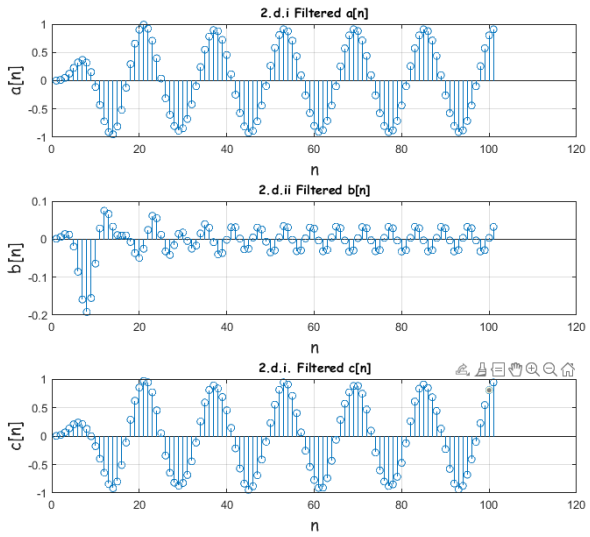
d) Using MATLAB's filter function, filter signals a[n], b[n] and c[n]. Plot your results. Explain your results.

Code:

```
clearvars
b0 = 0.00183555;
b1 = [1 1];
b2 = [1 1];
b3 = [1 1];
b4 = [1 1];
bf = b0*conv(conv(conv(b3,b4),b2),b1);
af = [1 -3.05434 3.8289993445 -2.29245273626 0.550744355605];

for n = 1:101;
   a(n) = cos(pi/8*n);
   b(n) = cos(pi/3*n);
```

```
   c(n) = cos(pi/8*n)+cos(pi/3*n);
end

n = [1:101];

y1 = filter(bf,af,a);
y2 = filter(bf,af,b);
y3 = filter(bf,af,c);
figure(17)
subplot(3,1,1)
stem(n,y1)
grid on
title('2.d.i Filtered a[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('a[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

subplot(3,1,2)
stem(n,y2)
grid on
title('2.d.ii Filtered b[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('b[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

subplot(3,1,3)
stem(n,y3)
grid on
title('2.d.i. Filtered c[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('c[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

Plots:



3. Allpass System

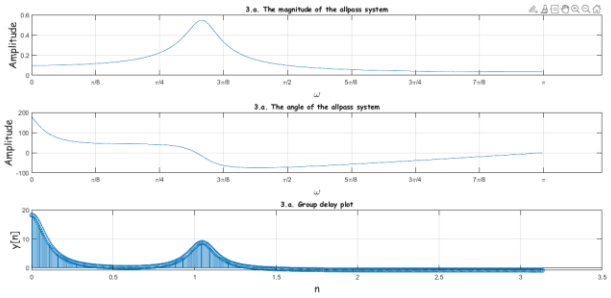
a) Using MATLAB's freqz function, plot the frequency response(both magnitude and phase). Using MATLAB's grpdelay function, plot the group delay of this system.

Code:

```
clearvars
a=0.9;
b=0.9*exp(1i.*pi./3);

b0 = [-a 1];
b1 = [(b*conj(b))-(b+conj(b))];
a0 = [1 -a];
a1 = [1 -(b+conj(b)) b*conj(b)];

bc = conv(b0, b1);
ac = conv(a0, a1);


[h, w] = freqz(bc, ac, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);

[y1, n1] = grpdelay(bc, ac, 512);

figure(18)

subplot(3,1,1)
plot(w,mag)
grid on
title('3.a. The magnitude of the allpass system', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,2)
plot(w,ang_h)
grid on
title('3.a. The angle of the allpass system', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
stem(n1,y1)
```

```
grid on
title('3.a. Group delay plot', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('y[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

plots:



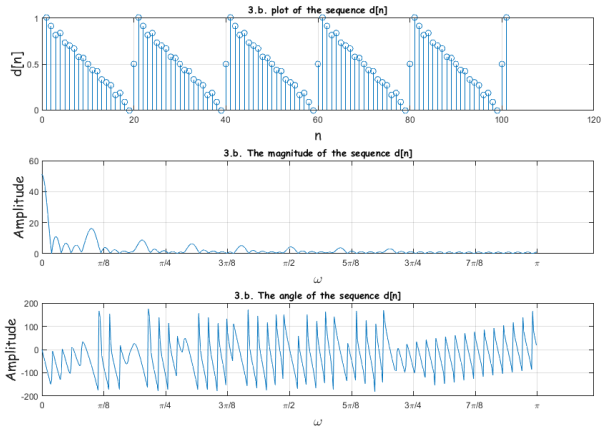
b) Generate and plot the first 101 samples of the sequence, d[n], where $d[n] = 1/2 + \frac{1}{\pi}\sum_{k=1}^{7}\frac{1}{k}\sin(k\omega_0 n)$ and $\omega_0=\pi/10$. Also plot the magnitude of the frequency spectrum of d[n].

Code:

```
clearvars

w0=pi/10;
for n = 1:101
   temp = 0;
   for k = 1:7
      temp = temp + sin(k*w0*n)/k;
   end
   d(n) = 0.5 + temp/pi;
end

n = [1:101];
[h, w] = freqz(d, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);
figure(19)

subplot(3,1,1)
stem(n,d)
grid on
title('3.b. plot of the sequence d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
```

```
subplot(3,1,2)
plot(w,mag)
grid on
title('3.b. The magnitude of the sequence d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('3.b. The angle of the sequence d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

Plots:



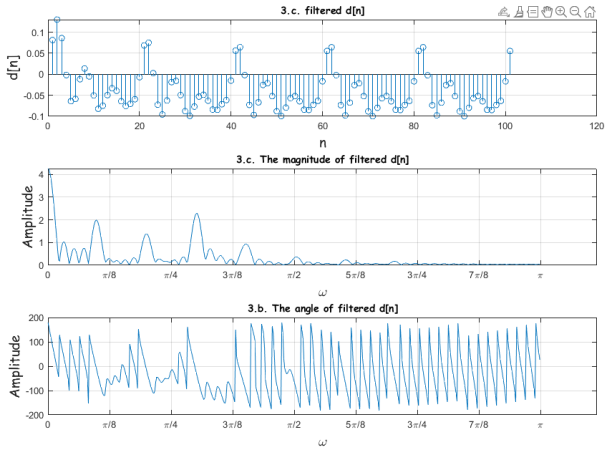
c) Using MATLAB's filter function, filter signal d[n]. Plot the output sequence and the magnitude of its frequency spectrum. Comment on your result.

Code:

```
clearvars
a=0.9;
b=0.9*exp(1i.*pi./3);

b0 = [-a 1];
b1 = [(b*conj(b))-(b+conj(b))];
a0 = [1 -a];
a1 = [1 -(b+conj(b)) b*conj(b)];

bc = conv(b0, b1);
```

```
ac = conv(a0, a1);

w0=pi/10;
for n = 1:101
   temp = 0;
   for k = 1:7
      temp = temp + sin(k*w0*n)/k;
   end
   d(n) = 0.5 + temp/pi;
end

n = [1:101];

y1 = filter(bc, ac, d);

[h, w] = freqz(y1, 1, 512);
mag = abs(h);
rad2deg = 180/pi;
ang_h = wrapTo180(unwrap(angle(h))*rad2deg);
figure(20)

subplot(3,1,1)
stem(n,y1)
grid on
title('3.c. filtered d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('n', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)

subplot(3,1,2)
plot(w,mag)
grid on
title('3.c. The magnitude of filtered d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})

subplot(3,1,3)
plot(w,ang_h)
grid on
title('3.b. The angle of filtered d[n]', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xlabel('\omega', 'fontname', 'Comic Sans MS', 'fontsize', 14)
ylabel('Amplitude', 'fontname', 'Comic Sans MS', 'fontsize', 14)
xticks([0 pi/8 pi/4 3*pi/8 pi/2 5*pi/8 3*pi/4 7*pi/8 pi])
xticklabels({'0' '\pi/8' '\pi/4' '3\pi/8' '\pi/2' '5\pi/8' '3\pi/4' '7\pi/8' '\pi'})
```

plots:



Comment:

The allpass filter passed through most of the magnitude from 0 to pi/2 and passed through most of the higher angles larger than 3pi/8. However, the filter worked well, as you can see that the filtered plot shows a somewhat clear oscillation that represents the original function's decline.