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1. Create 3 discrete-time one unit amplitude sinusoidal signals with the different linear frequencies, 0.05, 0.1 and 0.2 $sample^{-1}$, called $x_1[n], x_2[n]$ and $x_3[n]$ respectively. These signals can be written by either sin or cosine function and have arbitrary phase. All signals are generated at $n = [0: 100]$.

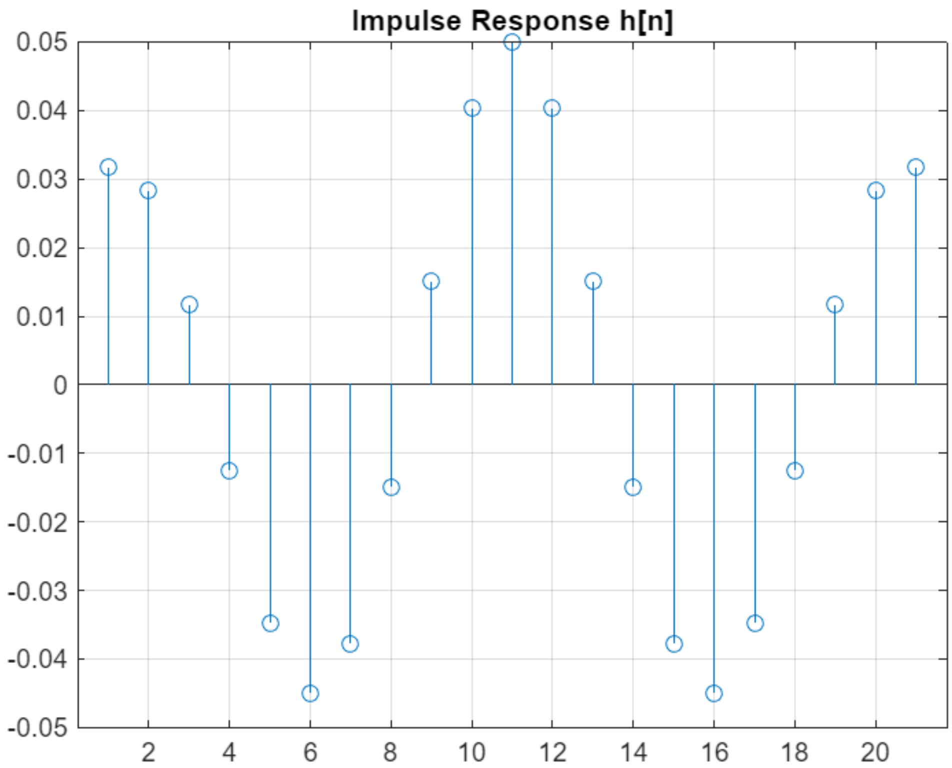
```
clc
clear

% Linear frequencies (sample^-1)
f = [0.05 0.1 0.2];

A = 1;
n = 0:100;
phi = pi/4;   % arbitrary phase

x1 = A*sin(2*pi*f(1)*n + phi);
x2 = A*sin(2*pi*f(2)*n + phi);
x3 = A*sin(2*pi*f(3)*n + phi);
```

2. With the given Finite Impulse Response, $h[n], n = [0: 20]$ compute the output signals from discrete-time convolution between $h[n]$ and the three sinusoidal signals in (1) called $y_1[n], y_2[n]$ and $y_3[n]$ respectively.

```
load('FIR.mat');
hn, n = 0:20;
```

```
hn = 1×21
    0.0318    0.0283    0.0117   -0.0125   -0.0347   -0.0450   -0.0378   -0.0149 ···
```

```
y1 = conv(x1, hn);
y2 = conv(x2, hn);
y3 = conv(x3, hn);

ny = 0:length(y1)-1;   % n = 0:120
figure
stem(hn)
grid on
title('Impulse Response h[n]')
```



ผลลัพธ์ที่สังเกตได้ (จากกราฟ):

x_1[n] (f=0.05): สัญญาณเอาต์พุต y_1[n] มีขนาด (Magnitude) ลดลงมากที่สุด

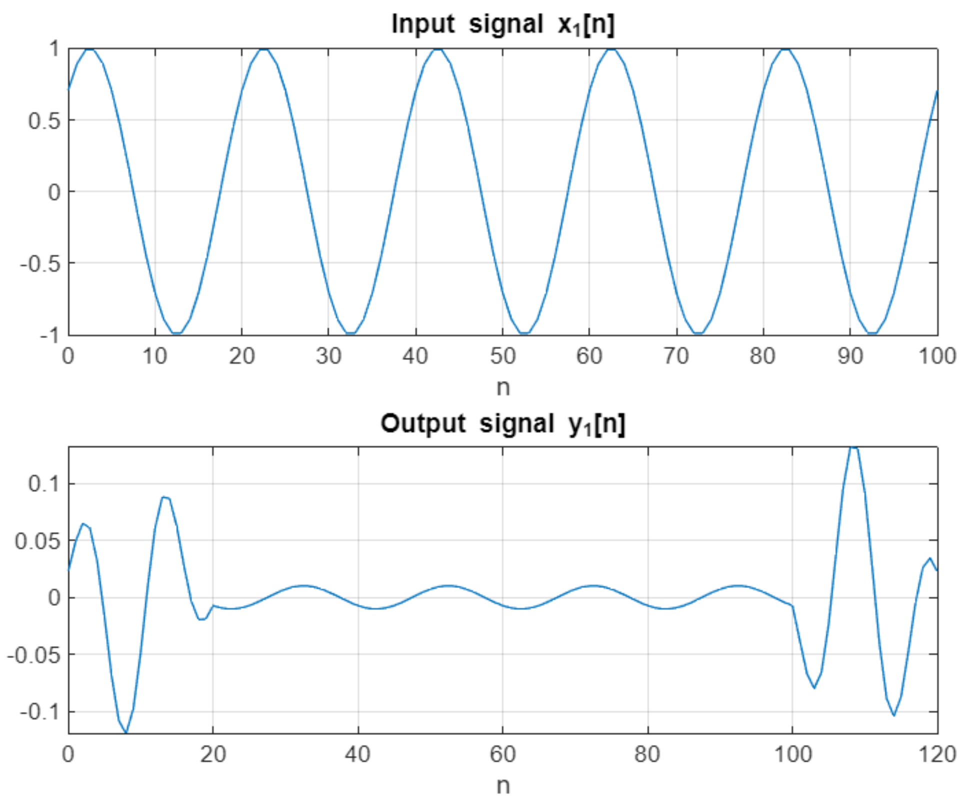
x_2[n]$ (f=0.1): สัญญาณเอาต์พุต y_2[n] มีขนาดลดลงปานกลาง

x_3[n]$ (f=0.2): สัญญาณเอาต์พุต y_3[n] มีขนาดลดลงน้อยที่สุด หรือเกือบเท่าเดิม

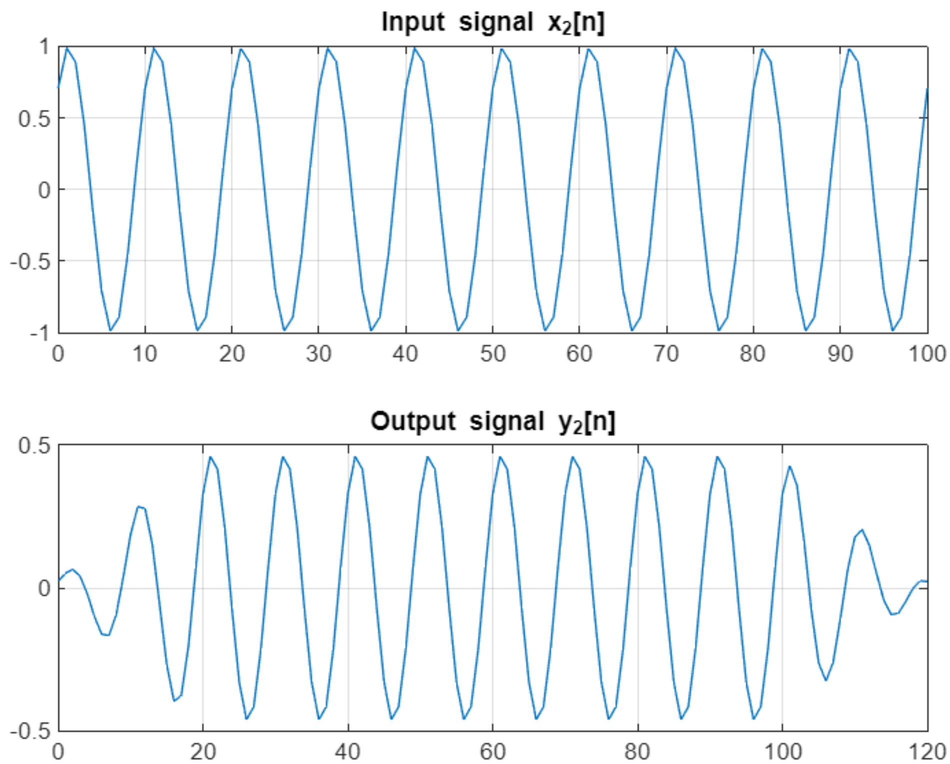
3. Display three pair of plots between input and output signals, $x_i[n], y_i[n]$ in figure 1-3 respectively. Note that $x_i[n]$ is 101 samples, $n = [0:100]$ but $y_i[n]$ is 121 samples, $n = [0:120]$. So they have to be plotted on different windows.

```
n_x = 0:100;              % input index
n_y = 0:length(y1)-1;     % output index (0:120)

figure(1)

subplot(2,1,1)
plot(n_x, x1)
grid on
title('Input signal x_1[n]')
xlabel('n')

subplot(2,1,2)
plot(n_y, y1)
```

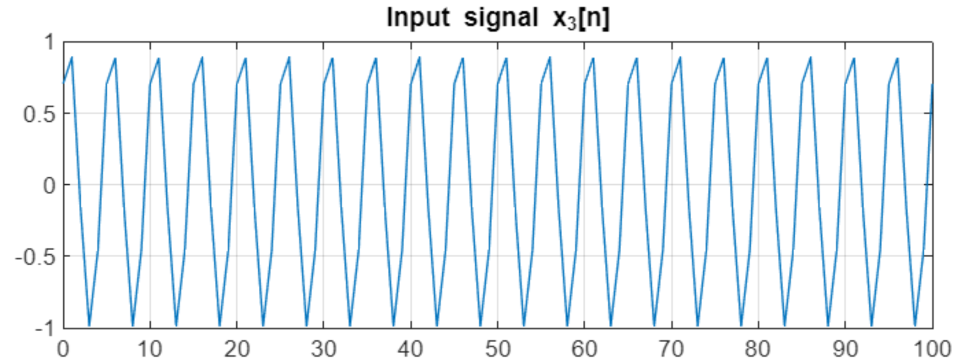
```
grid on
title('Output signal y_1[n]')
xlabel('n')
```

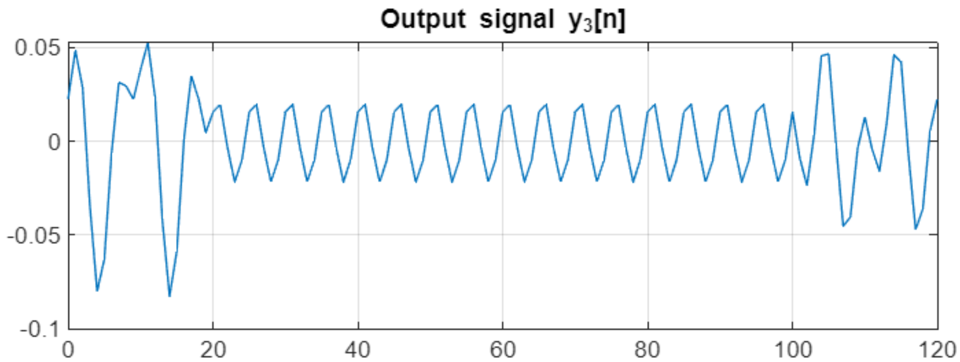



```
figure(2)

subplot(2,1,1)
plot(n_x, x2)
grid on
title('Input signal x_2[n]')

subplot(2,1,2)
plot(n_y, y2)
grid on
title('Output signal y_2[n]')
```




```
figure(3)

subplot(2,1,1)
plot(n_x, x3)
grid on
title('Input signal x_3[n]')

subplot(2,1,2)
plot(n_y, y3)
grid on
title('Output signal y_3[n]')
```





4. Find the Peak-to-Peak amplitude of the steady part (in the middle of the signal) of the output signals, $y_i[n]$. Can you tell that how this FIR respond to the sinusoidal signals at the different frequencies?

```
steady = 40:80;

pp_y1 = max(y1(steady)) - min(y1(steady));
pp_y2 = max(y2(steady)) - min(y2(steady));
pp_y3 = max(y3(steady)) - min(y3(steady));

fprintf('FIR Peak-to-Peak:\n')
```

```
FIR Peak-to-Peak:
```

```
fprintf('y1: %.4f\n', pp_y1)
```

```
y1: 0.0201
```

```
fprintf('y2: %.4f\n', pp_y2)
```

```
y2: 0.9197
```

```
fprintf('y3: %.4f\n', pp_y3)
```

```
y3: 0.0413
```

5. From the difference equation below,

$$y[n] = 1.5y[n-1] - 0.85y[n-2] + x[n]$$

compute the output signals from the three sinusoidal signals in (1) and zero initial conditions, $y[-2] = 0, y[-1] = 0$, called , $y_4[n], y_5[n]$ and $y_6[n]$ respectively.

```
b = 1;
a = [1 -1.5 0.85];

y4 = filter(b, a, x1);
y5 = filter(b, a, x2);
y6 = filter(b, a, x3);
n_x    = 0:100;       % input index
n_yi   = -2:100;      % output index (IIR)
y4_plot = [0 0 y4];
y5_plot = [0 0 y5];
y6_plot = [0 0 y6];
```

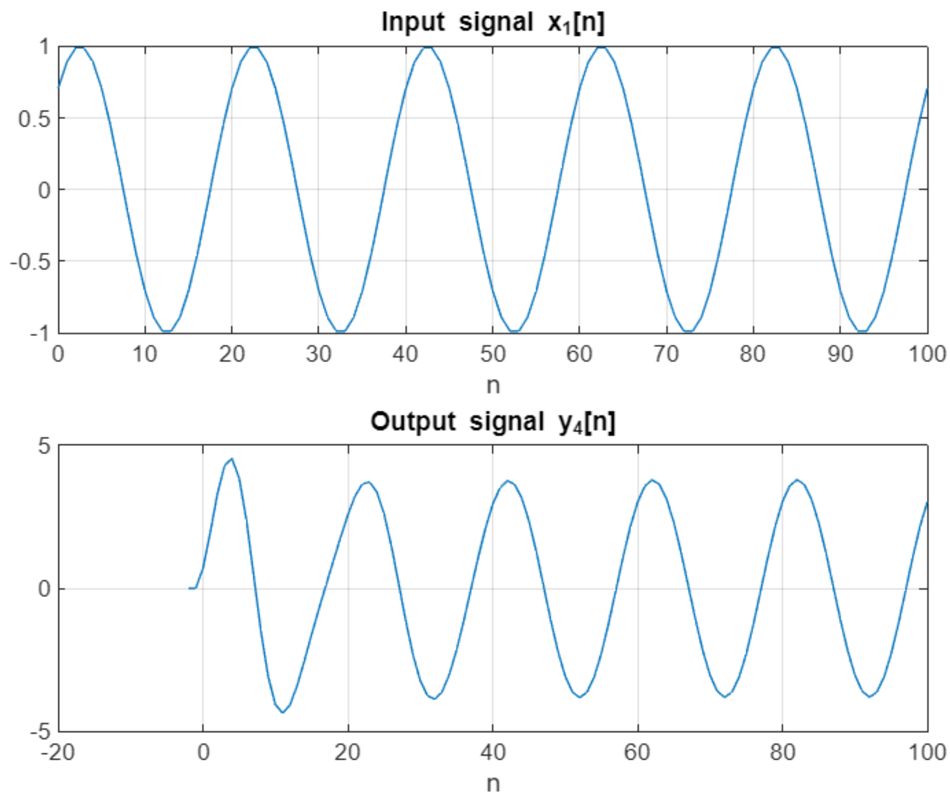
ผลลัพธ์ที่สังเกตได้ (จากกราฟ):

x_1[n] (f=0.05$): สัญญาณเอาต์พุต y_4[n] มีขนาด เพิ่มขึ้น มากที่สุด (Magnitude Gain สูง)

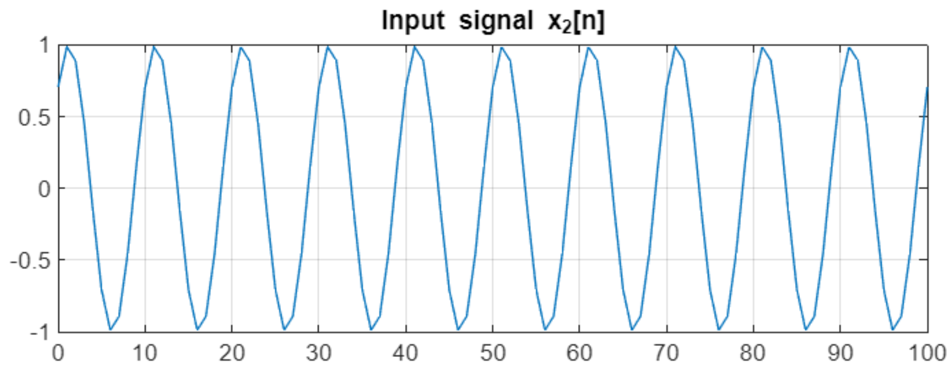
x_3[n] (f=0.2): สัญญาณเอาต์พุต y_6[n] มีขนาด เพิ่มขึ้น น้อยที่สุด (Magnitude Gain ต่ำ)

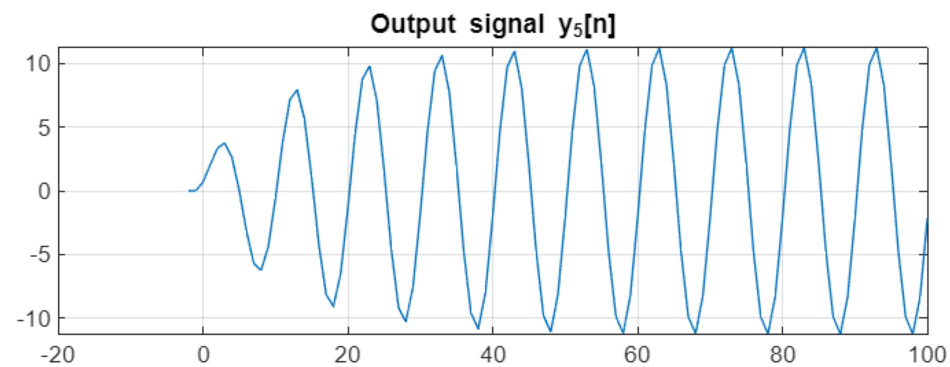
6. Display three pair of plots between input and output signals, $x_i[n], y_i[n]$ in figure 4-6 respectively. Note that $x_i[n]$ is 101 samples, $n = [0:100]$ but $y_i[n]$ is 103 samples, $n = [-2:100]$. So they have to be plotted on different windows.

```
    figure(4)

subplot(2,1,1)
plot(n_x, x1)
grid on
title('Input signal x_1[n]')
xlabel('n')

subplot(2,1,2)
plot(n_yi, y4_plot)
grid on
title('Output signal y_4[n]')
xlabel('n')
```

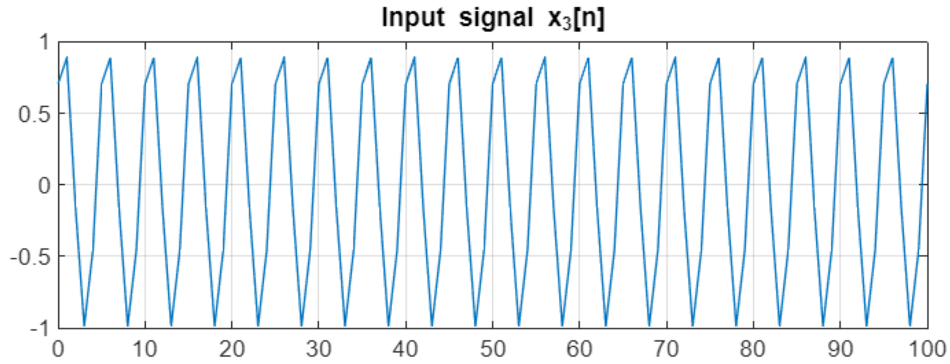


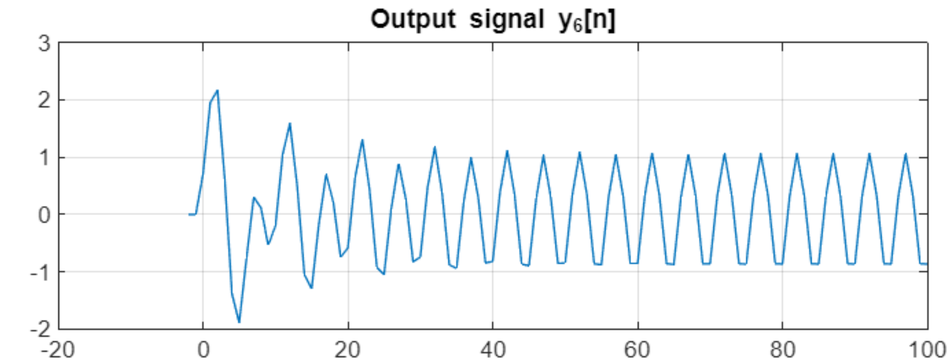

```
figure(5)

subplot(2,1,1)
plot(n_x, x2)
grid on
title('Input signal x_2[n]')

subplot(2,1,2)
plot(n_yi, y5_plot)
grid on
title('Output signal y_5[n]')
```






```
figure(6)

subplot(2,1,1)
plot(n_x, x3)
grid on
title('Input signal x_3[n]')

subplot(2,1,2)
plot(n_yi, y6_plot)
grid on
title('Output signal y_6[n]')
```





7. Find the Peak-to-Peak amplitude of the steady part (at the end of the signal) of the output signals, $y_i[n]$. Can you tell that how this difference equation (IIR) respond to the sinusoidal signals at the different frequencies?

```
steady_iir = 70:100;

pp_y4 = max(y4(steady_iir)) - min(y4(steady_iir));
pp_y5 = max(y5(steady_iir)) - min(y5(steady_iir));
pp_y6 = max(y6(steady_iir)) - min(y6(steady_iir));

fprintf('IIR Peak-to-Peak:\n')
```

```
IIR Peak-to-Peak:
```

```
fprintf('y4: %.4f\n', pp_y4)
```

```
y4: 7.5893
```

```
fprintf('y5: %.4f\n', pp_y5)
```

```
y5: 22.5002
```

```
fprintf('y6: %.4f\n', pp_y6)
```

```
y6: 1.9359
```

8. Can you tell how the two systems (FIR and IIR) operate? Which one is better? Why?

%การสรุปผล (Conclusion)

% FIR System (Convolution): ระบบนี้ทำหน้าที่เป็น High-Pass Filter (HPF) เนื่องจากมีการลดทอนสัญญาณที่ความถี่ต่ำ (f=0.05) มากกว่าที่ความถี่สูง (f=0.2)

% IIR System (Difference Eq.): ระบบนี้ทำหน้าที่เป็น Low-Pass Filter (LPF) เนื่องจากมีการขยายสัญญาณที่ความถี่ต่ำ (f=0.05) มากกว่าที่ความถี่สูง (f=0.2)

%The output signals obtained from the difference equation have longer duration due to the system memory. Therefore, the input and output signals are plotted in separate windows with different time indices.

Save .Fig

```
studentID = '66010892';
allFigureHandles = findall(0, 'Type', 'figure');
for i = 1:length(allFigureHandles)
    figName = sprintf('%s_Figure%d.fig', studentID, i);
    savefig(allFigureHandles(i), figName);
    disp(['Saved: ' figName]);
end
```

```
Saved: 66010892_Figure1.fig
Saved: 66010892_Figure2.fig
Saved: 66010892_Figure3.fig
Saved: 66010892_Figure4.fig
Saved: 66010892_Figure5.fig
Saved: 66010892_Figure6.fig
Saved: 66010892_Figure7.fig
```