Name: **Nguyễn Đình Khánh Vy**

Section: **22161043**

Laboratory Exercise 2

DISCRETE-TIME SYSTEMS: TIME-DOMAIN REPRESENTATION

2.1 SIMULATION OF DISCRETE-TIME SYSTEMS

Project 2.1 The Moving Average System

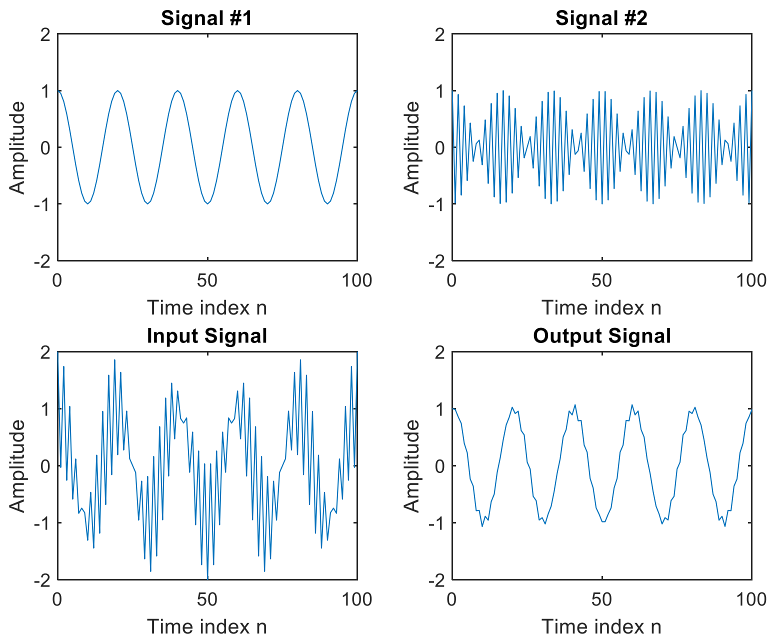
A copy of Program P2_1 is given below:

```
% Program P2_1
% Simulation of an M-point Moving Average Filter
% Generate the input signal
n = 0:100;
s1 = cos(2*pi*0.05*n); % A low-frequency sinusoid
s2 = cos(2*pi*0.47*n); % A high frequency sinusoid
x = s1+s2;
% Implementation of the moving average filter
M = input('Desired length of the filter = ');
num = ones(1,M);
y = filter(num,1,x)/M;
% Display the input and output signals
clf;
subplot(2,2,1);
plot(n, s1);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Signal #1');
subplot(2,2,2);
plot(n, s2);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Signal #2');
subplot(2,2,3);
plot(n, x);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Input Signal');
subplot(2,2,4);
plot(n, y);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Signal');
```

`axis;`

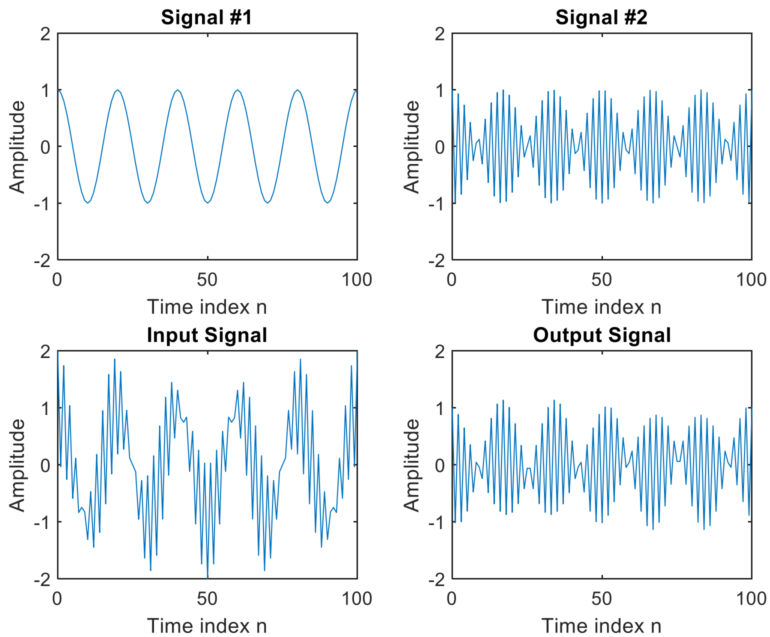
Answers:

Q2.1 The output sequence generated by running the above program for M = 2 with `x[n] = s1[n]+s2[n]` as the input is shown below.



The component of the input `x[n]` suppressed by the discrete-time system simulated by this program is **Signal #2 – the high frequency one (it is a low pass filter)**

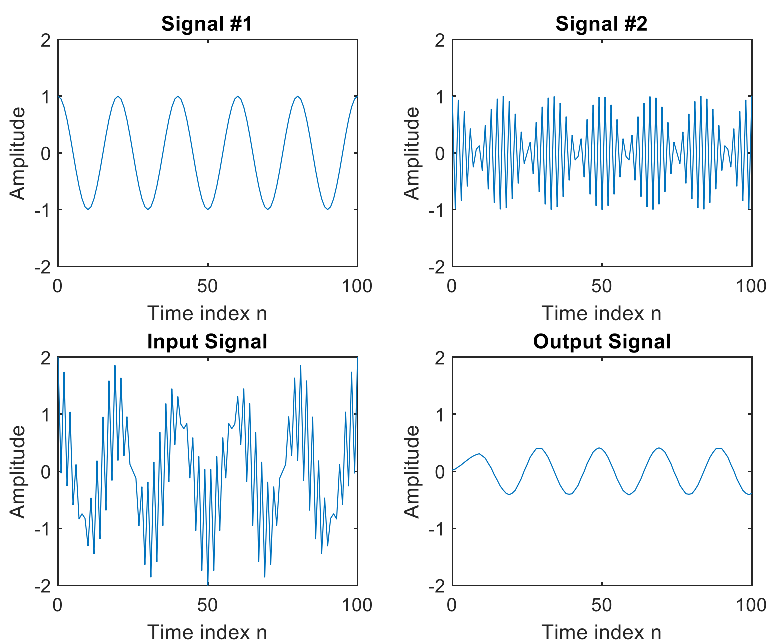
Q2.2 Program P2_1 is modified to simulate the LTI system `y[n] = 0.5(x[n]-x[n-1])` and process the input `x[n] = s1[n]+s2[n]` resulting in the output sequence shown below:



The effect of changing the LTI system on the input is - **The system is now a high pass filter.**

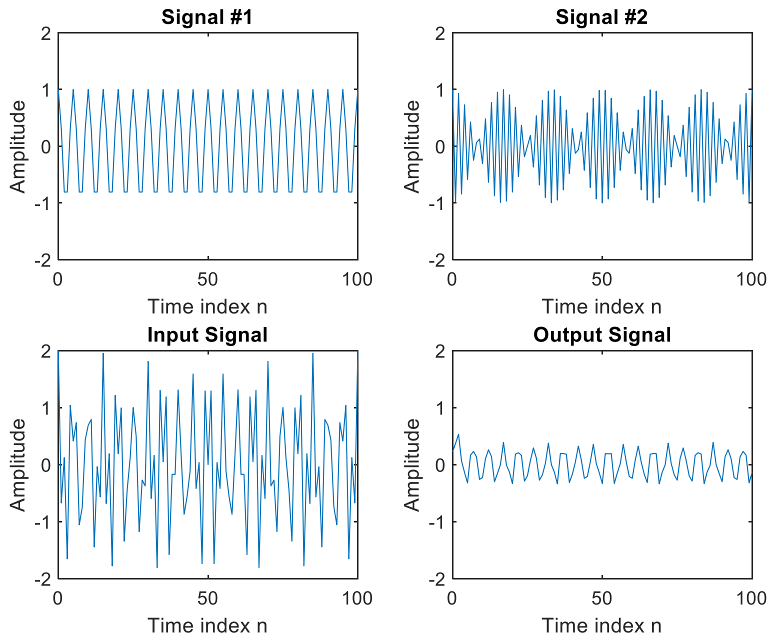
Q2.3 Program P2_1 is run for the following values of filter length M and following values of the frequencies of the sinusoidal signals `s1[n]` and `s2[n]`. The output generated for these different values of `M` and the frequencies are shown below. From these plots we make the following observations

$$f1 = 0.05, f2 = 0.47, M = 10$$



From these plots we make the following observations: the low pass

f1 = 0.2, f2 = 0.47, M = 3



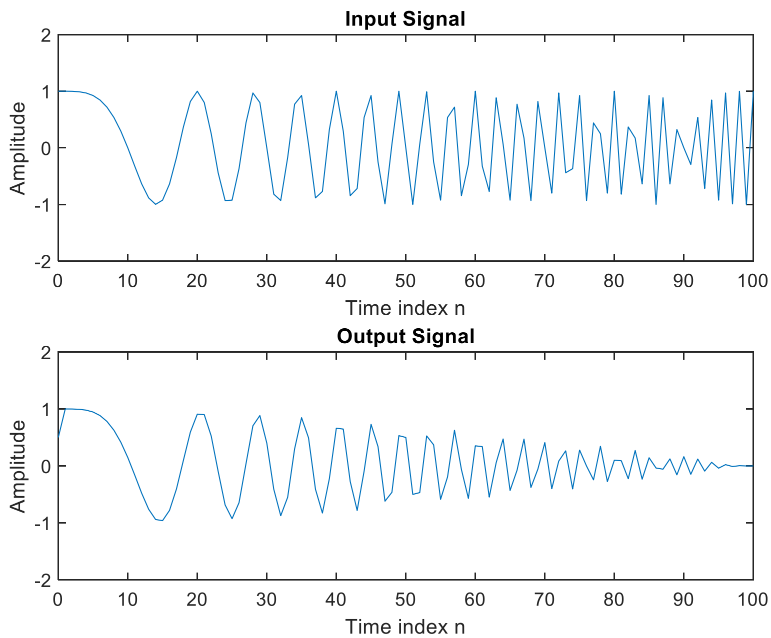
From these plots we make the following observations: this filter performs more smoothing than in the case M=2

Q2.4 The required modifications to Program P2_1 by changing the input sequence to a swept-frequency sinusoidal signal (length 101, minimum frequency 0, and a maximum frequency 0.5) as the input signal (see Program P1_7) are listed below:

```
% Program Q2.4
% Simulation of an M-point Moving Average Filter
% Generate the input signal
n = 0:100;
a = pi/200; % A low-frequency sinusoid
b = 0; % A high frequency sinusoid
arg = a*n.*n + b*n;
x = cos(arg);
% Implementation of the moving average filter
M = input('Desired length of the filter = ');
num = ones(1,M);
y = filter(num,1,x)/M;
% Display the input and output signals
clf;
subplot(2,1,1);
plot(n, x);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Input Signal');
subplot(2,1,2);
plot(n, y);
```

```
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Signal');
axis;
```

The output signal generated by running this program is plotted below.



The results of Questions Q2.1 and Q2.2 from the response of this system to the swept-frequency signal can be explained as follows: **a low pass**

Project 2.2 (Optional) A Simple Nonlinear Discrete-Time System

A copy of Program P2_2 is given below:

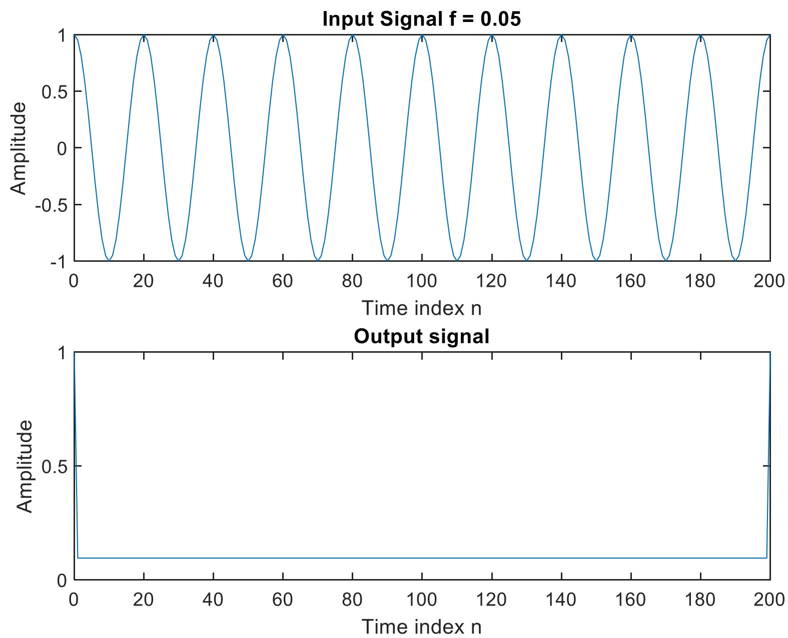
```
% Program P2_2
% Generate a sinusoidal input signal
clf;
n = 0:200;
x = cos(2*pi*0.05*n);
% Compute the output signal
x1 = [x 0 0];        % x1[n] = x[n+1]
x2 = [0 x 0];        % x2[n] = x[n]
x3 = [0 0 x];        % x3[n] = x[n-1]
y = x2.*x2-x1.*x3;
y = y(2:202);
% Plot the input and output signals
subplot(2,1,1)
plot(n, x)
xlabel('Time index n');ylabel('Amplitude');
title('Input Signal')
```

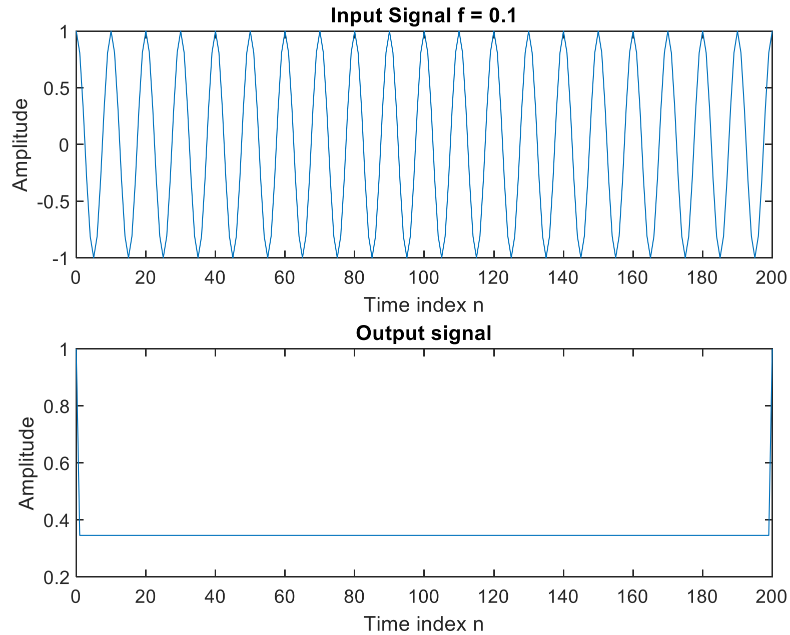
```
subplot(2,1,2)
plot(n,y)
xlabel('Time index n');ylabel('Amplitude');
title('Output signal');
```

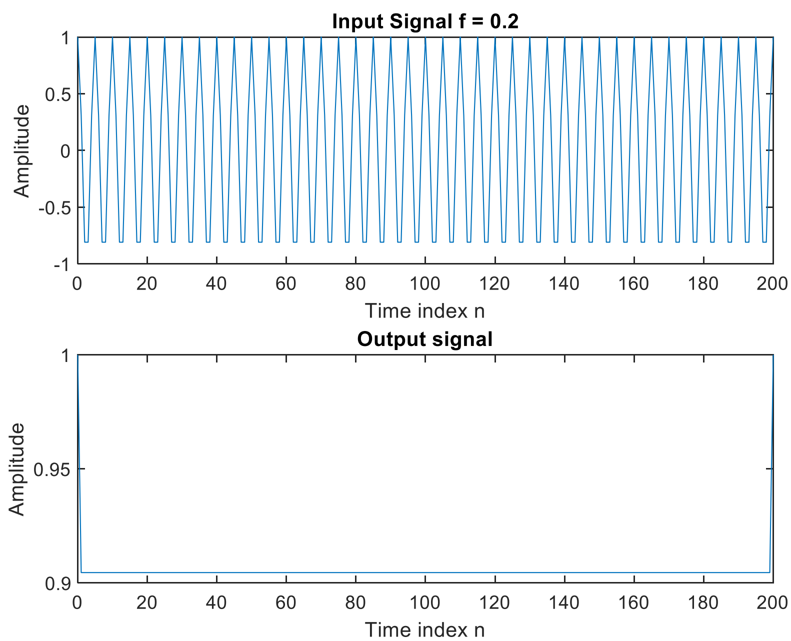
Answers:

Q2.5 The sinusoidal signals with the following frequencies as the input signals were used to generate the output signals: **f = 0.05, f = 0.1, f = 0.2**

The output signals generated for each of the above input signals are displayed below:





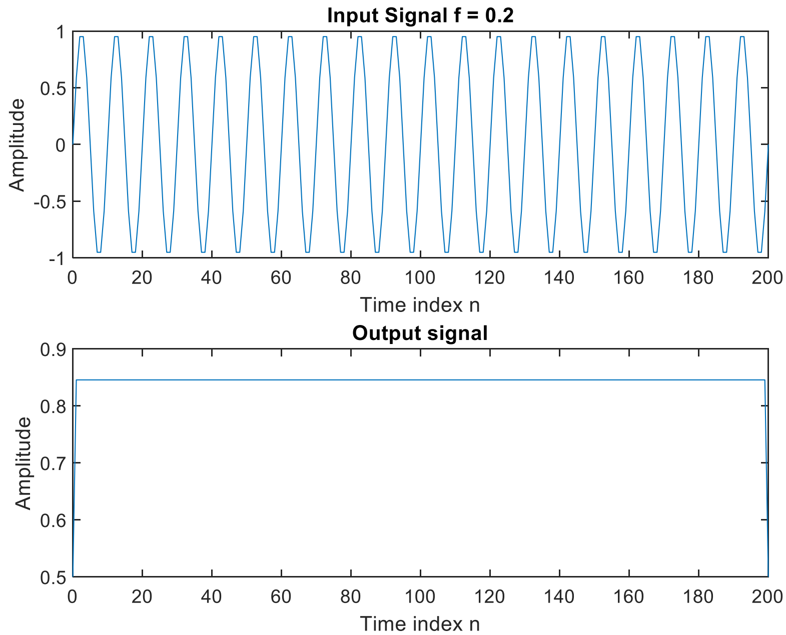


The output signals depend on the frequencies of the input signal according to the following rules:

This observation can be explained mathematically as follows:

Q2.6 The output signal generated by using sinusoidal signals of the form $x[n] = \sin(\omega_o n) + K$ as the input signal is shown below for the following values of ω_o and K -

$$\omega_o = 0.2\ \text{pi},\ K = 0.5$$



The dependence of the output signal `yt[n]` on the DC value K can be explained as -

Project 2.3 Linear and Nonlinear Systems

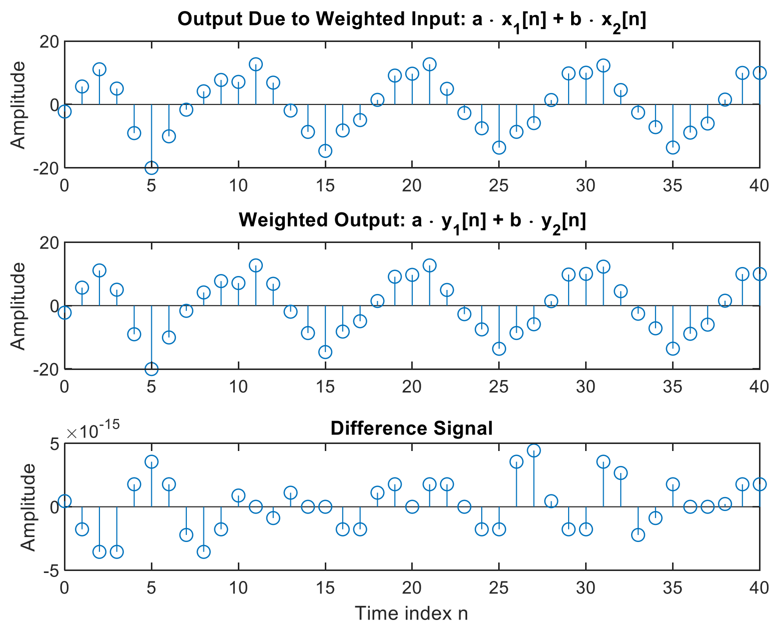
A copy of Program P2_3 is given below:

```
% Program P2_3
% Generate the input sequences
clf;
n = 0:40;
a = 2;b = -3;
x1 = cos(2*pi*0.1*n);
x2 = cos(2*pi*0.4*n);
x = a*x1 + b*x2;
num = [2.2403 2.4908 2.2403];
den = [1 -0.4 0.75];
ic = [0 0]; % Set zero initial conditions
y1 = filter(num,den,x1,ic); % Compute the output y1[n]
y2 = filter(num,den,x2,ic); % Compute the output y2[n]
y = filter(num,den,x,ic); % Compute the output y[n]
yt = a*y1 + b*y2;
d = y - yt; % Compute the difference output d[n]
% Plot the outputs and the difference signal
subplot(3,1,1)
stem(n,y);
ylabel('Amplitude');
title('Output Due to Weighted Input: a \cdot x_{1}[n] + b
\cdot x_{2}[n]');
subplot(3,1,2)
stem(n,yt);
```

```
ylabel('Amplitude');
title('Weighted Output: a \cdot y_{1}[n] + b \cdot
y_{2}[n]');
subplot(3,1,3)
stem(n,d);
xlabel('Time index n');ylabel('Amplitude');
title('Difference Signal');
```

Answers:

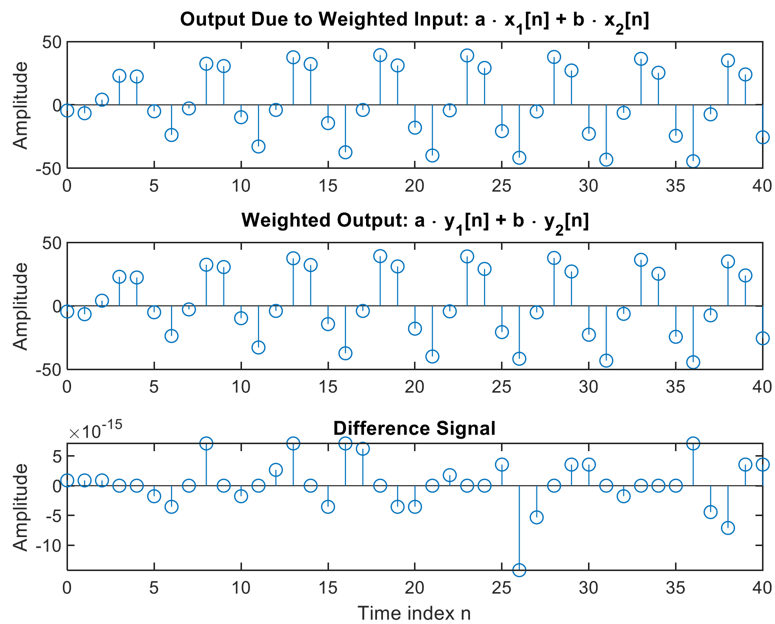
Q2.7 The outputs `y[n]`, obtained with weighted input, and `yt[n]`, obtained by combining the two outputs `y1[n]` and `y2[n]` with the same weights, are shown below along with the difference between the two signals:

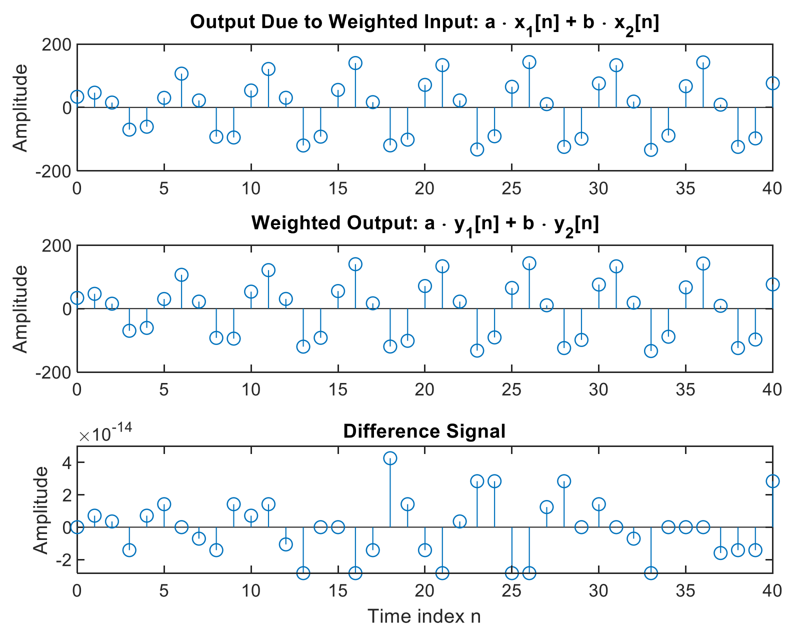


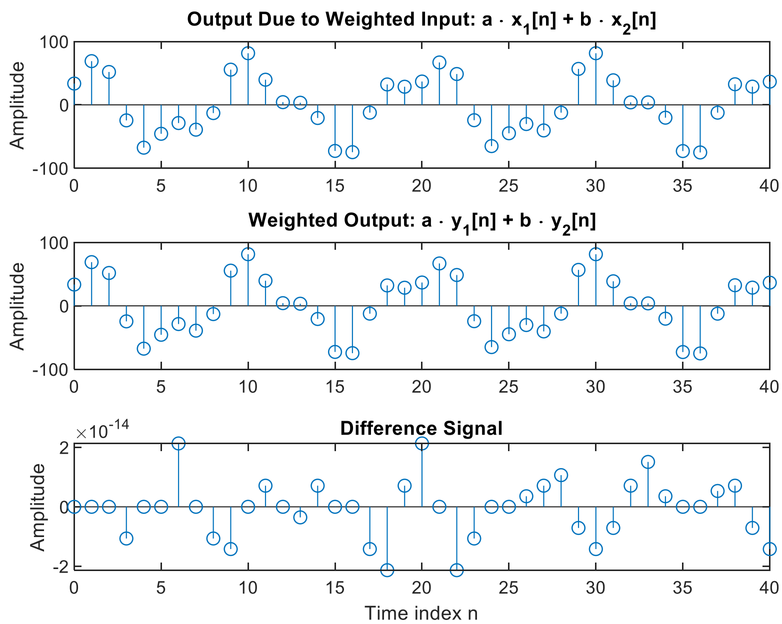
The two sequences are - **the same up to numerical roundoff**

The system is - **Linear**

Q2.8 Program P2_3 was run for the following three different sets of values of the weighting constants, `a` and `b`, and the following three different sets of input frequencies:
a = 1, b = -3, f1 = 0.01, f2 = 0.2
a = 10, b = 5, f1 = 0.2, f2 = 0.5
a = 5, b = 10, f1 = 0.25, f2 = 0.1
The plots generated for each of the above three cases are shown below:


Output Due to Weighted Input: a · x1[n] + b · x2[n]
Weighted Output: a · y1[n] + b · y2[n]
Difference Signal
Amplitude
Time index n

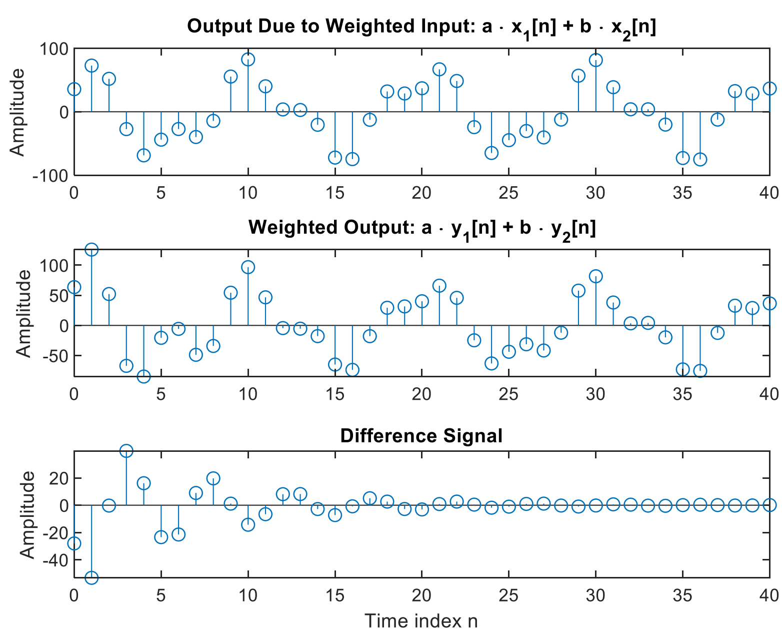

Output Due to Weighted Input: a · x1[n] + b · x2[n]
Weighted Output: a · y1[n] + b · y2[n]
Difference Signal
Amplitude
Time index n



Based on these plots we can conclude that the system with different weights is – **Linear**

Q2.9 Program 2_3 was run with the following non-zero initial conditions – **ic = [2 3];**

The plots generated are shown below -

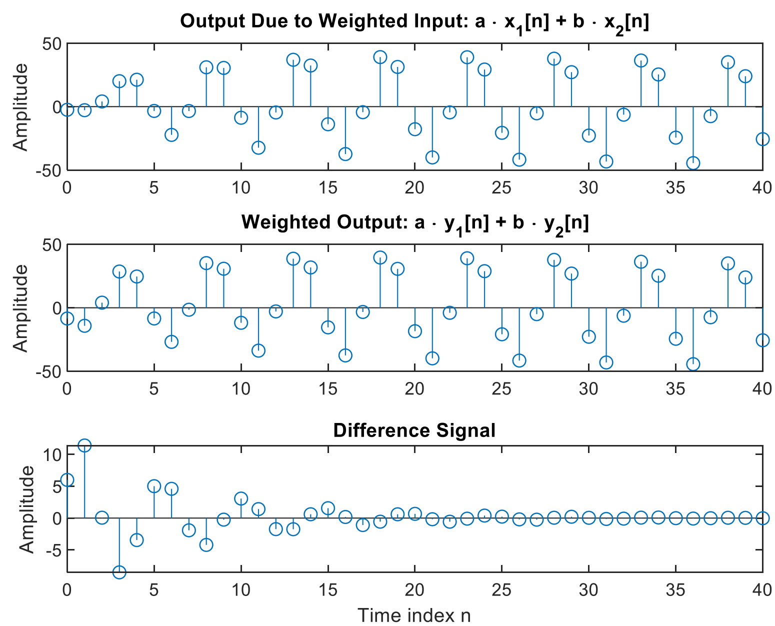


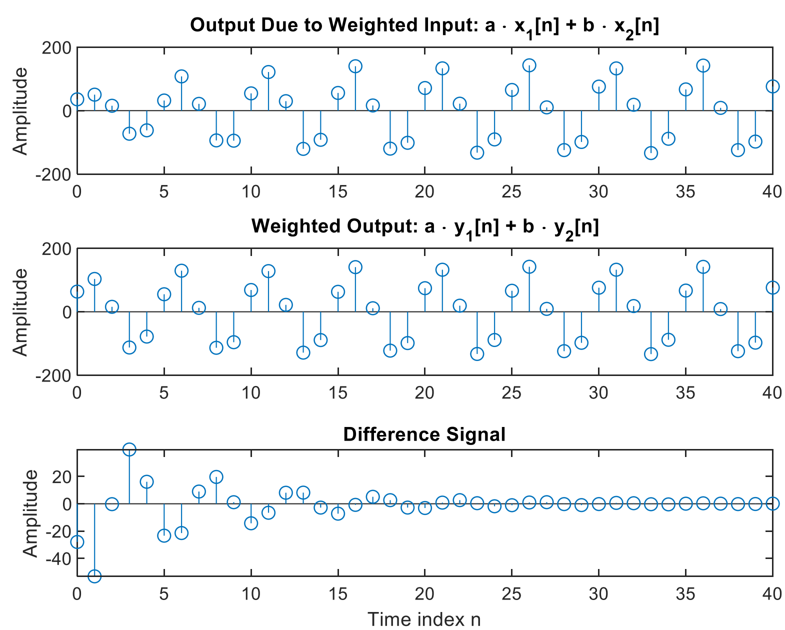
Based on these plots we can conclude that the system with nonzero initial conditions is – **Nonlinear**

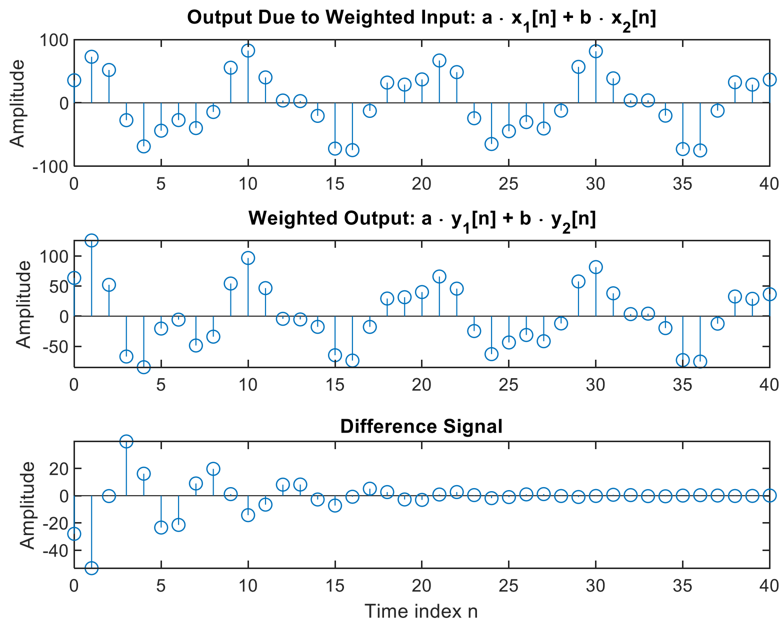
Q2.10 Program P2_3 was run with nonzero initial conditions and for the following three different sets of values of the weighting constants, `a` and `b`, and the following three different sets of input frequencies:

a = 1, b = -3, f1 = 0.01, f2 = 0.2
a = 10, b = 5, f1 = 0.2, f2 = 0.5
a = 5, b = 10, f1 = 0.25, f2 = 0.1

The plots generated for each of the above three cases are shown below:







Based on these plots we can conclude that the system with nonzero initial conditions and different weights is – **Nonlinear**

Q2.11 Program P2_3 was modified to simulate the system:

```
y[n] = x[n]x[n–1]
```

The output sequences `y1[n]`, `y2[n]`, and `y[n]` of the above system generated by running the modified program are shown below:

< Insert MATLAB figure(s) here. Copy from figure window(s) and paste. >

Comparing `y[n]` with `yt[n]` we conclude that the two sequences are –

This system is –

Project 2.4 Time-invariant and Time-varying Systems

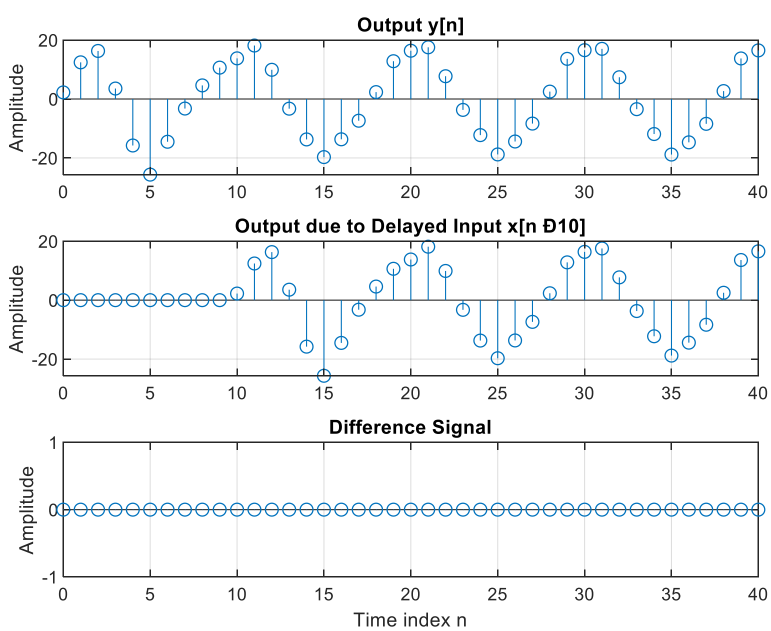
A copy of Program P2_4 is given below:

```
% Program P2_4
% Generate the input sequences
clf;
n = 0:40; D = 10;a = 3.0;b = -2;
x = a*cos(2*pi*0.1*n) + b*cos(2*pi*0.4*n);
xd = [zeros(1,D) x];
num = [2.2403 2.4908 2.2403];
den = [1 -0.4 0.75];
ic = [0 0]; % Set initial conditions
```

```
% Compute the output y[n]
y = filter(num,den,x,ic);
% Compute the output yd[n]
yd = filter(num,den,xd,ic);
% Compute the difference output d[n]
d = y - yd(1+D:41+D);
% Plot the outputs
subplot(3,1,1)
stem(n,y);
ylabel('Amplitude');
title('Output y[n]'); grid;
subplot(3,1,2)
stem(n,yd(1:41));
ylabel('Amplitude');
title(['Output due to Delayed Input x[n Ð',
num2str(D),']']); grid;
subplot(3,1,3)
stem(n,d);
xlabel('Time index n'); ylabel('Amplitude');
title('Difference Signal'); grid;
```

Answers:

Q2.12 The output sequences `y[n]` and `yd[n-10]` generated by running Program P2_4 are shown below -

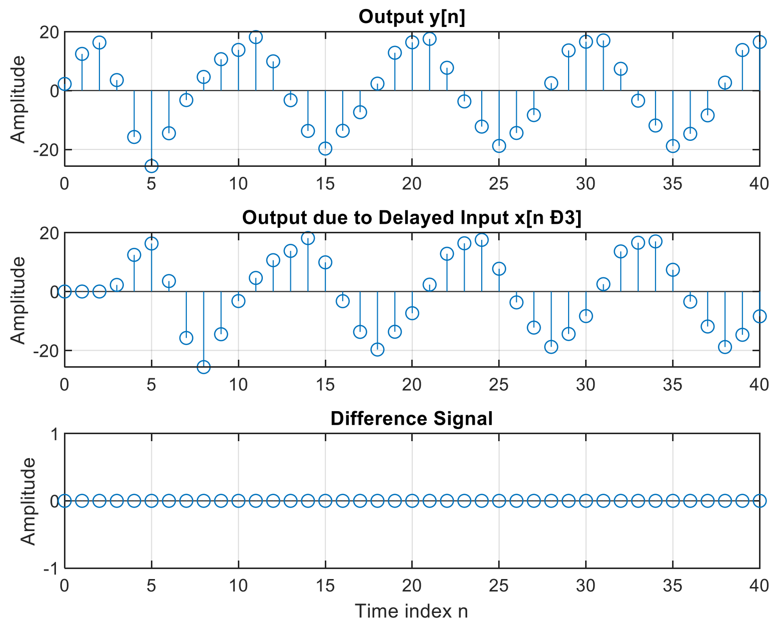


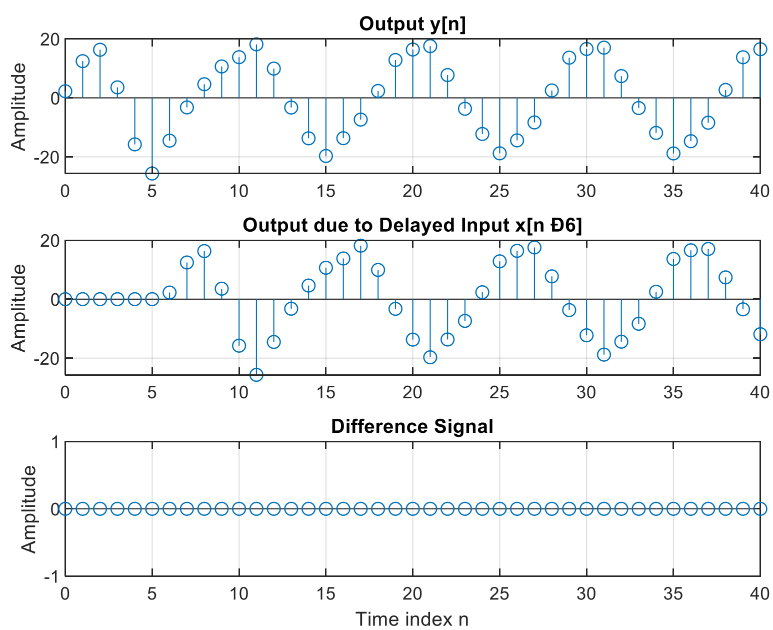
These two sequences are related as follows **y[n-10] = yd[n]**

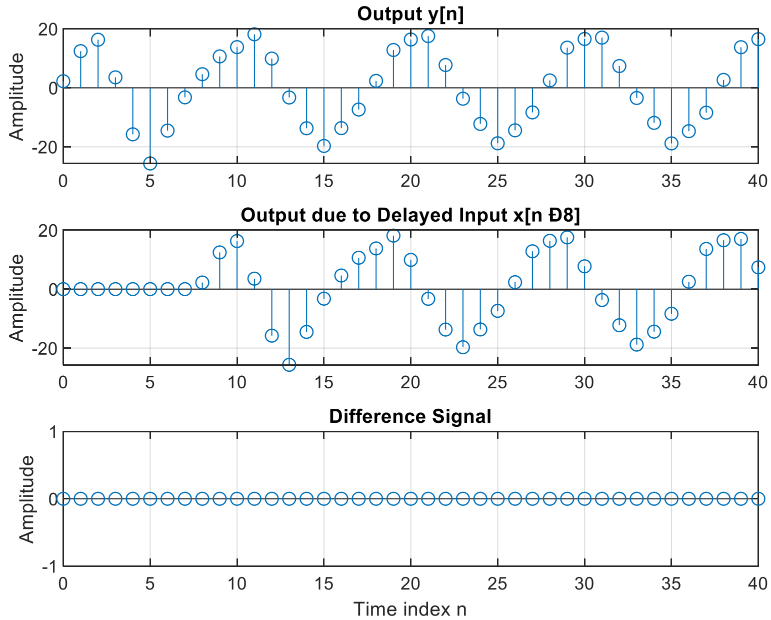
The system is **Time Invariant**

Q2.13 The output sequences `y[n]` and `yd[n-D]` generated by running Program P2_4 for the following values of the delay variable D: **3, 6, 8**

are shown below -







In each case, these two sequences are related as follows **y[n-D] = yd[n]**

The system is **Time Invariant**

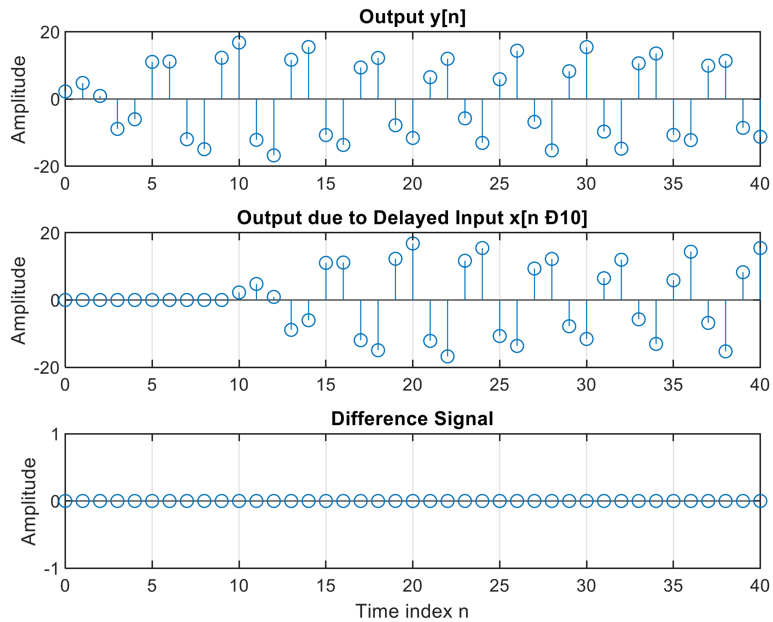
Q2.14 The output sequences `y[n]` and `yd[n-10]` generated by running Program P2_4 for the following values of the input frequencies

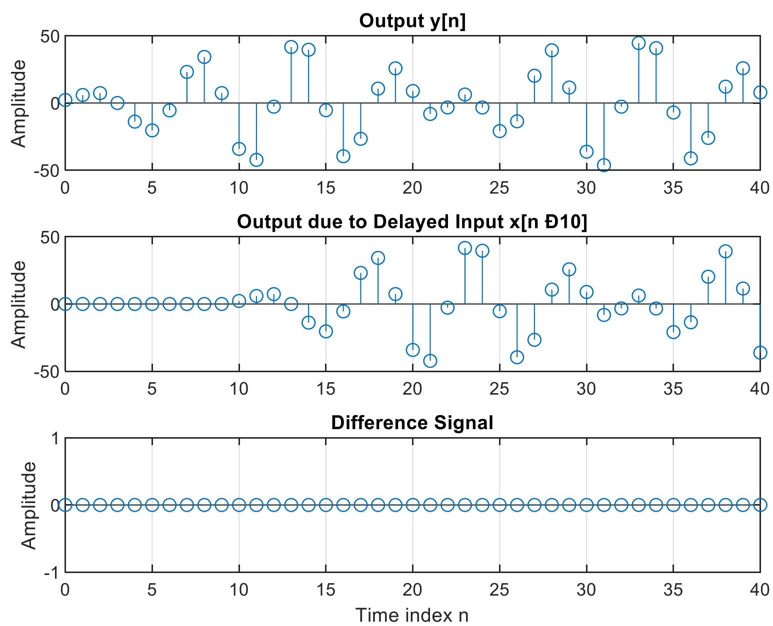
f1 = 0.25, f2 = 0.3

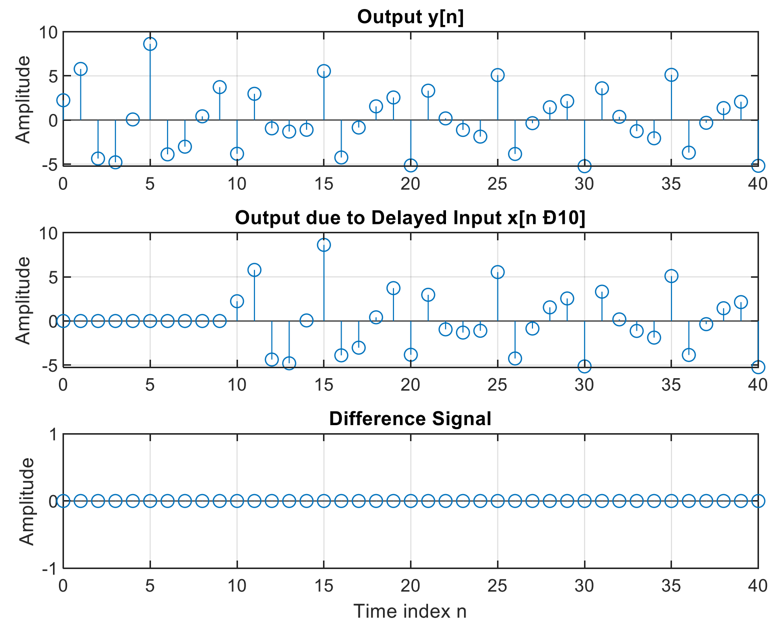
f1 = 0.15, f2 = 0.2

f1 = 0.3, f2 = 0.5

are shown below -


Output y[n]
Amplitude
20
0
-20
0
5
10
15
20
25
30
35
40
Output due to Delayed Input x[n Ð10]
Amplitude
20
0
-20
Difference Signal
Amplitude
1
0
-1
Time index n

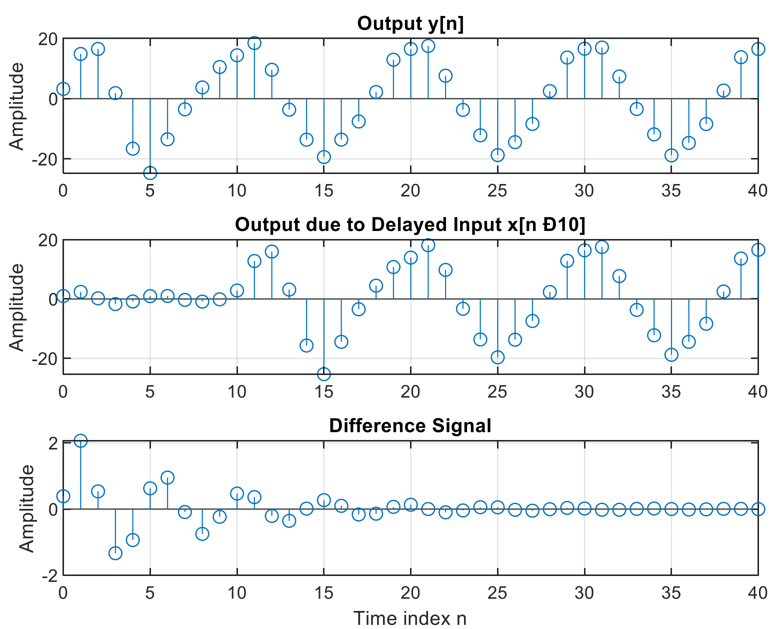

Output y[n]
Amplitude
50
0
-50
0
5
10
15
20
25
30
35
40
Output due to Delayed Input x[n Ð10]
Amplitude
50
0
-50
Difference Signal
Amplitude
1
0
-1
Time index n



In each case, these two sequences are related as follows **y[n-10] = yd[n]**

The system is **Time Invariant**

Q2.15 The output sequences `y[n]` and `yd[n-10]` generated by running Program P2_4 for non-zero initial conditions are shown below -



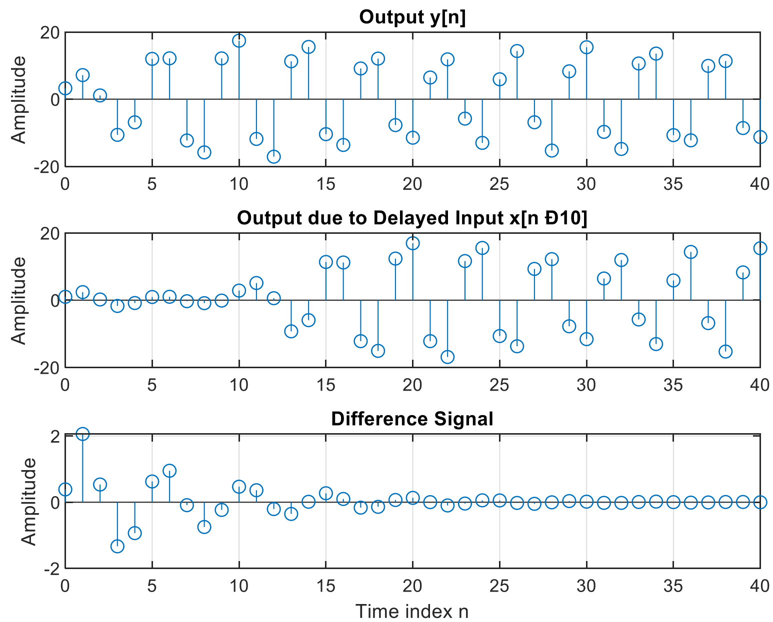
These two sequences are related as follows **yd[n] is NOT equal to the shift of y[n]**

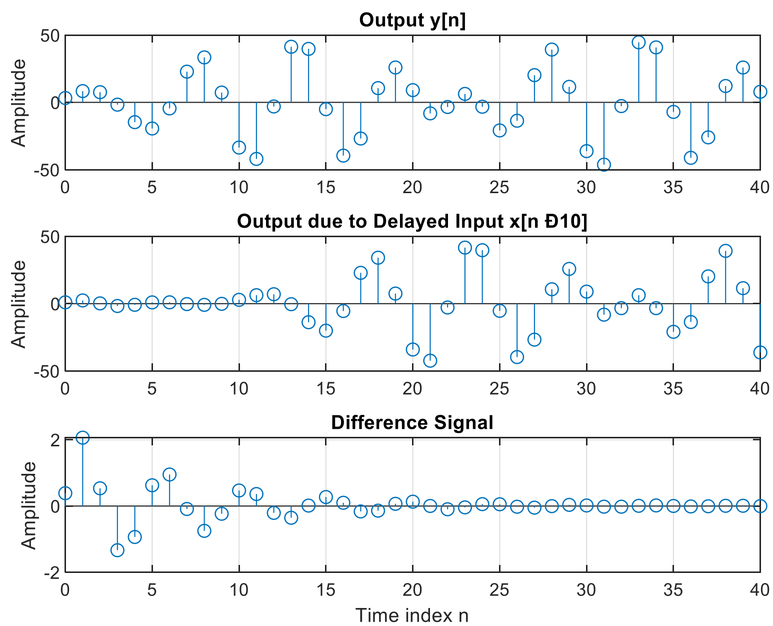
The system is **Time Varying**

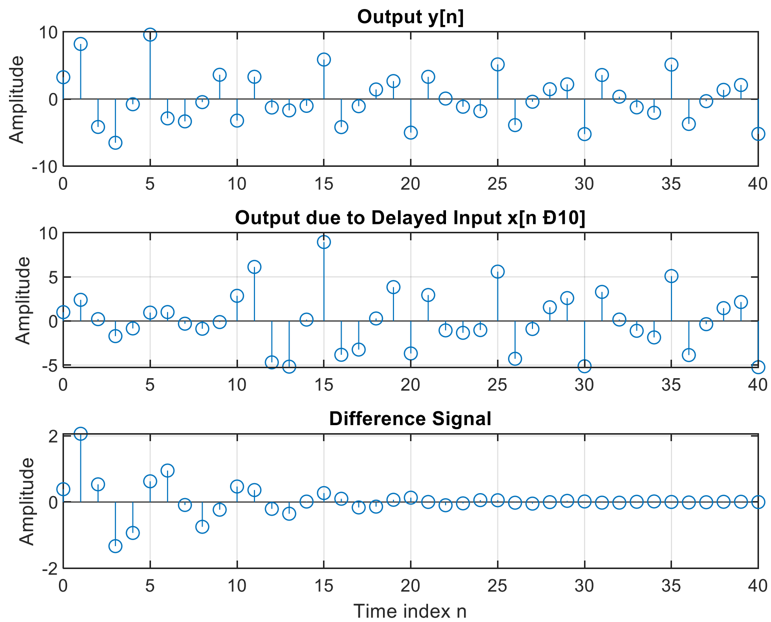
Q2.16 The output sequences `y[n]` and `yd[n-10]` generated by running Program P2_4 for non-zero initial conditions and following values of the input frequencies

f1 = 0.25, f2 = 0.3
f1 = 0.15, f2 = 0.2
f1 = 0.3, f2 = 0.5

are shown below -







In each case, these two sequences are related as follows **yd[n] is NOT given by the shift of y[n].**

The system is **Time Varying.**

Q2.17 The modified Program 2_4 simulating the system

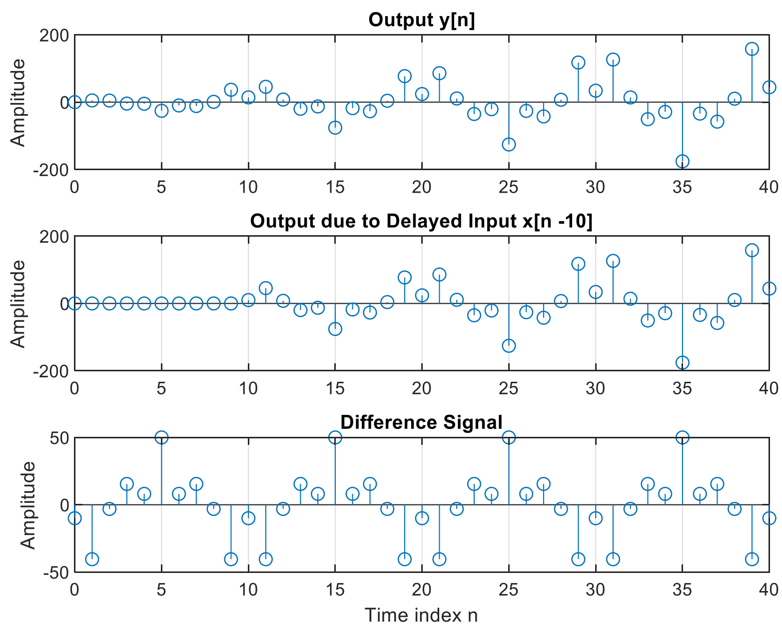
$$y[n] = n\,x[n] + x[n-1]$$

is given below:

```
% Program Q2.17
% Generate the input sequences
clf;
n = 0:40; D = 10;a = 3.0;b = -2;
x = a*cos(2*pi*0.1*n) + b*cos(2*pi*0.4*n);
xd = [zeros(1,D) x];
nd = 0:length(xd)-1;
% Compute the output y[n]
y = (n .* x) + [0 x(1:40)];
% Compute the output yd[n]
yd = (nd .* xd) + [0 xd(1:length(xd)-1)];
% Compute the difference output d[n]
d = y - yd(1+D:41+D);
% Plot the outputs
subplot(3,1,1)
stem(n,y);
ylabel('Amplitude');
title('Output y[n]'); grid;
```

```
subplot(3,1,2)
stem(n,yd(1:41));
ylabel('Amplitude');
title(['Output due to Delayed Input x[n -',
num2str(D),']']); grid;
subplot(3,1,3)
stem(n,d);
xlabel('Time index n'); ylabel('Amplitude');
title('Difference Signal'); grid;
```

The output sequences `y[n]` and `yd[n-10]` generated by running modified Program P2_4 are shown below –



These two sequences are related as follows **yd[n] is NOT the shifted version of y[n].**

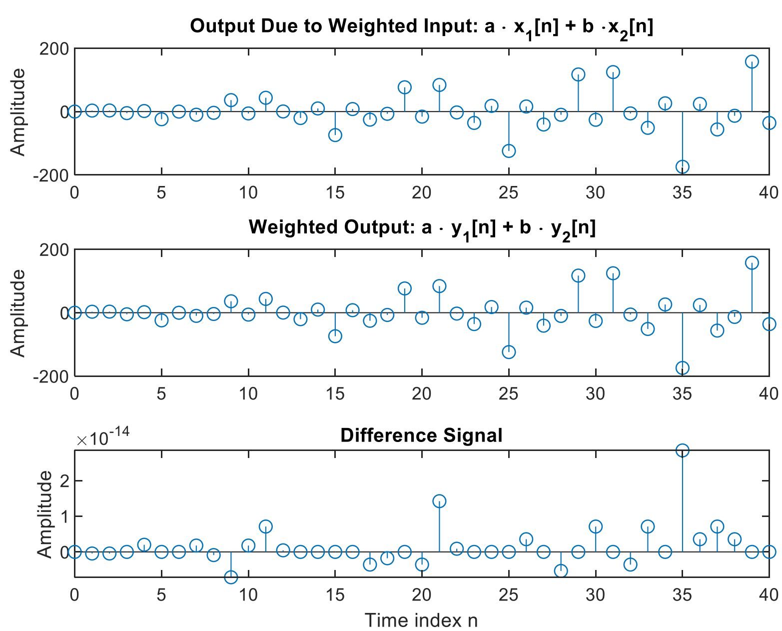
The system is **Time Varying.**

Q2.18 (optional) The modified Program P2_3 to test the linearity of the system of Q2.18 is shown below:

```
% Program Q2.18
% Modify P2_3 for Q2.18.
% Generate the input sequences
clf;
n = 0:40;
a = 2;b = -3;
x1 = cos(2*pi*0.1*n);
x2 = cos(2*pi*0.4*n);
x = a*x1 + b*x2;
y1 = (n .* x1) + [0 x1(1:40)]; % Compute the output y1[n]
```

```
y2 = (n .* x2) + [0 x2(1:40)]; % Compute the output y2[n]
y = (n .* x) + [0 x(1:40)]; % Compute the output y[n]
yt = a*y1 + b*y2;
d = y - yt; % Compute the difference output d[n]
% Plot the outputs and the difference signal
subplot(3,1,1)
stem(n,y);
ylabel('Amplitude');
title('Output Due to Weighted Input: a \cdot x_{1}[n] + b
\cdotx_{2}[n]');
31
subplot(3,1,2)
stem(n,yt);
ylabel('Amplitude');
title('Weighted Output: a \cdot y_{1}[n] + b \cdot
y_{2}[n]');
subplot(3,1,3)
stem(n,d);
xlabel('Time index n');ylabel('Amplitude');
title('Difference Signal');
```

The outputs `y[n]` and `yt[n]` obtained by running the modified program P2_3 are shown below:



The two sequences are **The same up to numerical roundoff.**

The system is **Linear**

2.2 LINEAR TIME-INVARIANT DISCRETE-TIME SYSTEMS

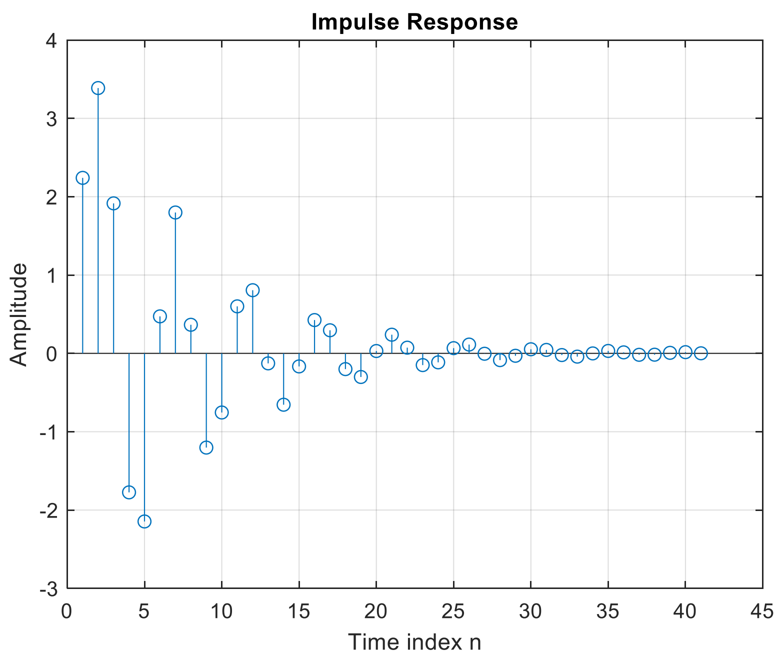
Project 2.5 Computation of Impulse Responses of LTI Systems

A copy of Program P2_5 is shown below:

```
% Program P2_5
% Compute the impulse response y
clf;
N = 40;
num = [2.2403 2.4908 2.2403];
den = [1 -0.4 0.75];
y = impz(num,den,N);
% Plot the impulse response
stem(y);
xlabel('Time index n'); ylabel('Amplitude');
title('Impulse Response'); grid;
```

Answers:

Q2.19 The first 41 samples of the impulse response of the discrete-time system of Project 2.3 generated by running Program P2_5 is given below:



Q2.20 The required modifications to Program P2_5 to generate the impulse response of the following causal LTI system:

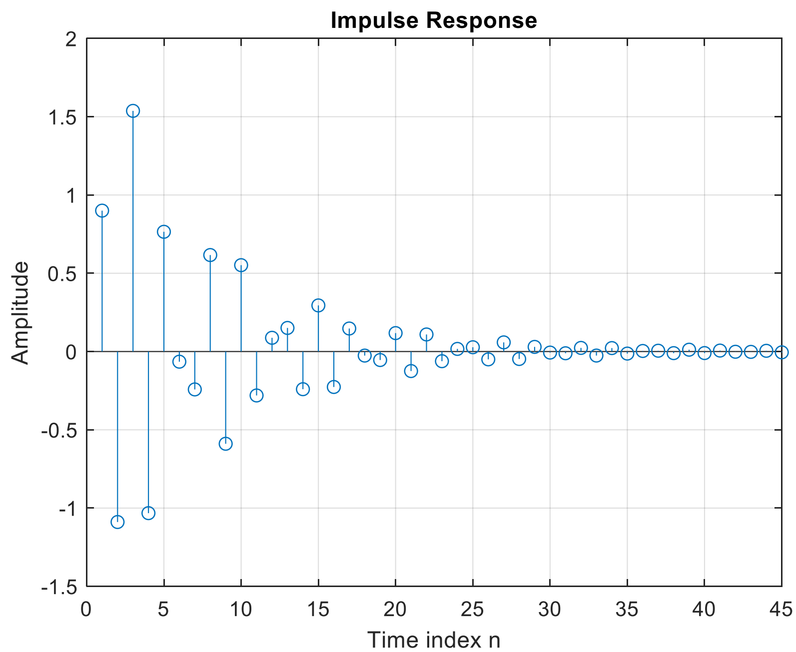
$$y[n] + 0.71y[n-1] - 0.46y[n-2] - 0.62y[n-3]$$

$$= 0.9x[n] - 0.45x[n-1] + 0.35x[n-2] + 0.002x[n-3]$$

are given below:

```
%Program Q2.20
N = 45;
den = [1 0.71 -0.46 -0.62 ];
num = [0.9 -0.45 0.35 0.002];
y = impz(num,den,N);
% Plot the impulse response
stem(y);
xlabel('Time index n'); ylabel('Amplitude');
title('Impulse Response'); grid;
```

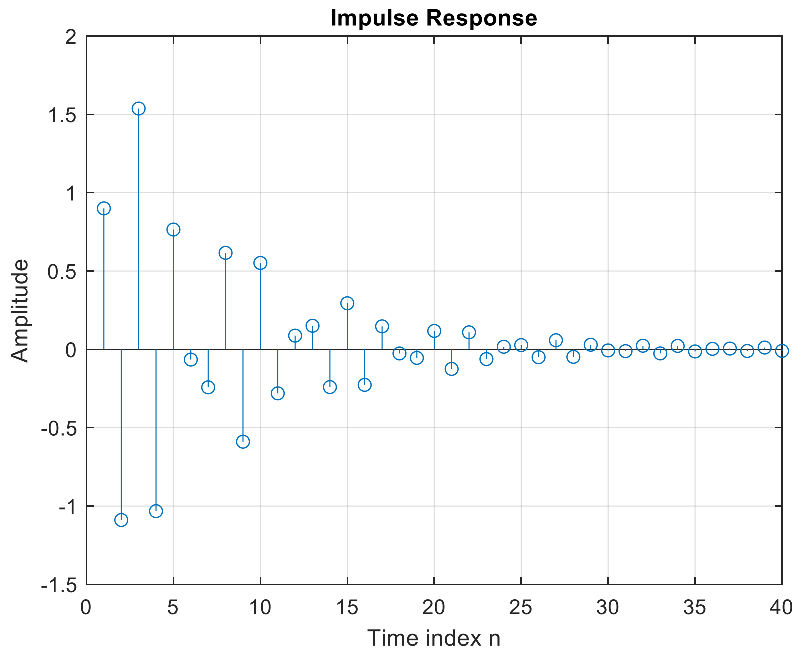
The first 45 samples of the impulse response of this discrete-time system generated by running the modified is given below:



Q2.21 The MATLAB program to generate the impulse response of a causal LTI system of Q2.20 using the `filter` command is indicated below:

```
%Program Q2.21
N = 40;
den = [1 0.71 -0.46 -0.62 ];
num = [0.9 -0.45 0.35 0.002];
x = [1 zeros(1,39)];
y = filter(num,den,x);
% Plot the impulse response
stem(y);
xlabel('Time index n'); ylabel('Amplitude');
title('Impulse Response'); grid;
```

The first 40 samples of the impulse response generated by this program are shown below:

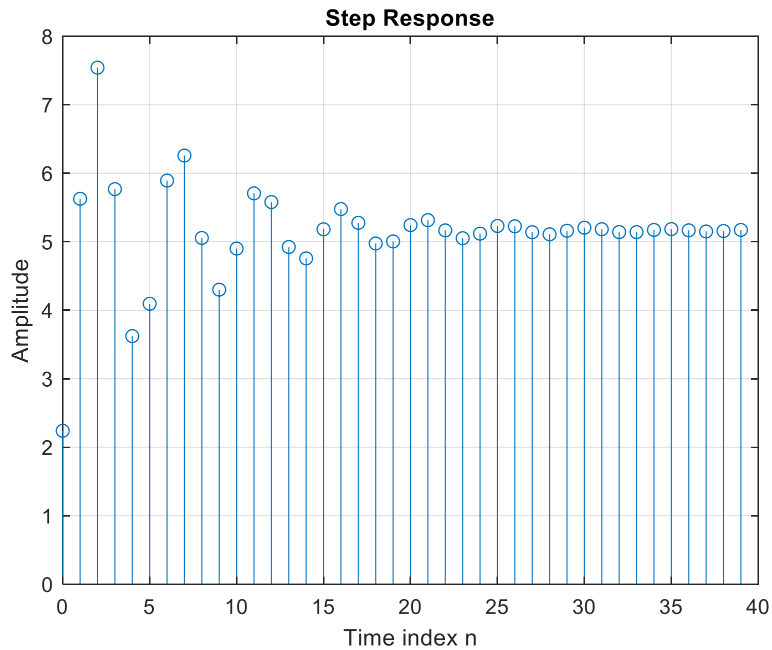


Comparing the above response with that obtained in Question Q2.20 we conclude - **The 2 ways are the same**

Q2.22 The MATLAB program to generate and plot the step response of a causal LTI system is indicated below:

```
% Program Q2_22
% Compute the step response s
clf;
N = 40;
n = 0:N-1;
num = [2.2403 2.4908 2.2403];
den = [1.0 -0.4 0.75];
% input: unit step
x = [ones(1,N)];
% output
y = filter(num,den,x);
% Plot the step response
stem(n,y);
xlabel('Time index n'); ylabel('Amplitude');
title('Step Response'); grid;
```

The first 40 samples of the step response of the LTI system of Project 2.3 are shown below



Project 2.6 Cascade of LTI Systems

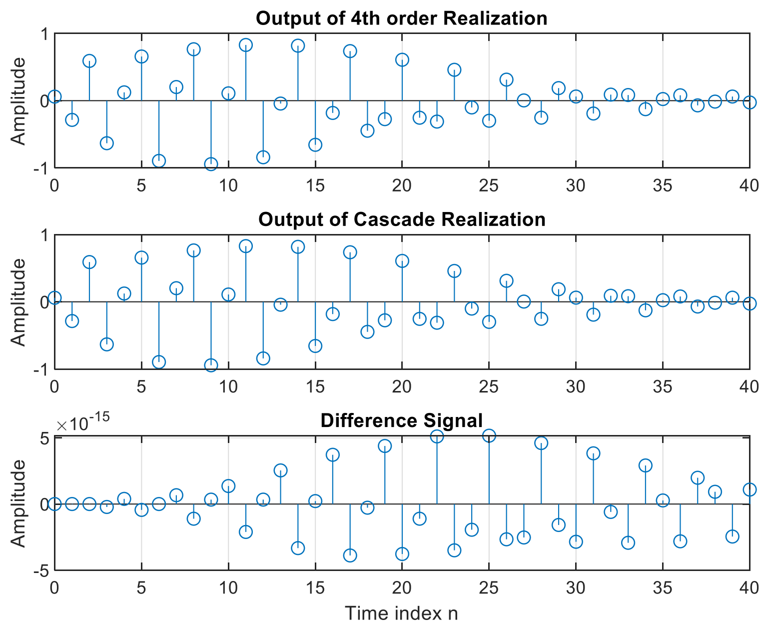
A copy of Program P2_6 is given below:

```
% Program P2_6
% Cascade Realization
clf;
x = [1 zeros(1,40)]; % Generate the input
n = 0:40;
% Coefficients of 4th order system
den = [1 1.6 2.28 1.325 0.68];
num = [0.06 -0.19 0.27 -0.26 0.12];
% Compute the output of 4th order system
y = filter(num,den,x);
% Coefficients of the two 2nd order systems
num1 = [0.3 -0.2 0.4];den1 = [1 0.9 0.8];
num2 = [0.2 -0.5 0.3];den2 = [1 0.7 0.85];
% Output y1[n] of the first stage in the cascade
y1 = filter(num1,den1,x);
% Output y2[n] of the second stage in the cascade
y2 = filter(num2,den2,y1);
% Difference between y[n] and y2[n]
d = y - y2;
% Plot output and difference signals
subplot(3,1,1);
stem(n,y);
ylabel('Amplitude');
title('Output of 4th order Realization'); grid;
```

```
subplot(3,1,2);
stem(n,y2)
ylabel('Amplitude');
title('Output of Cascade Realization'); grid;
subplot(3,1,3);
stem(n,d)
xlabel('Time index n');ylabel('Amplitude');
title('Difference Signal'); grid;
```

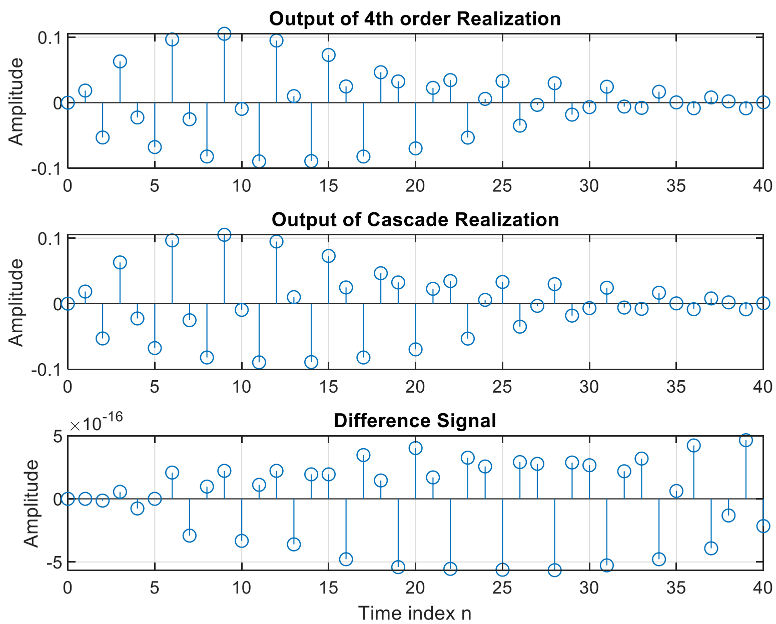
Answers:

Q2.23 The output sequences `y[n]`, `y2[n]`, and the difference signal `d[n]` generated by running Program P2_6 are indicated below:



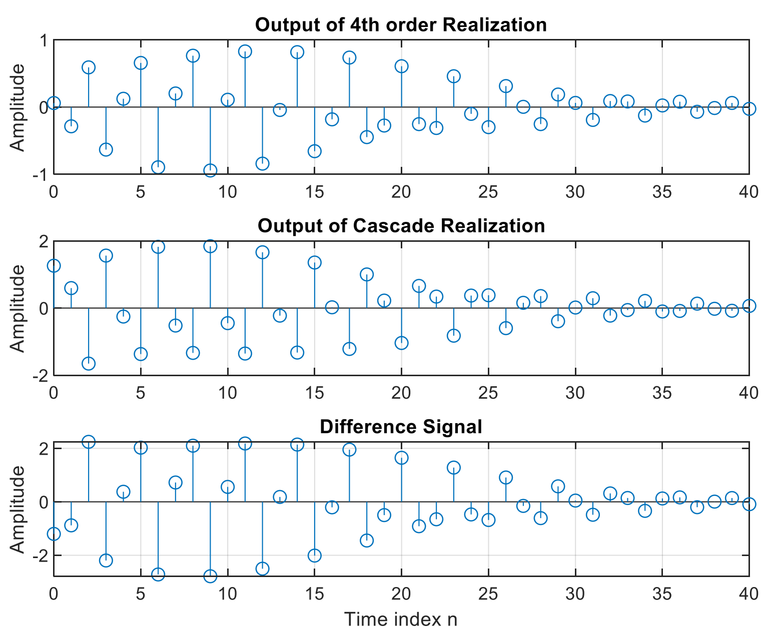
The relation between `y[n]` and `y2[n]` is **same up to numerical roundoff**

Q2.24 The sequences generated by running Program P2_6 with the input changed to a sinusoidal sequence are as follows:



The relation between `y[n]` and `y2[n]` in this case is **same up to numerical roundoff**

Q2.25 The sequences generated by running Program P2_6 with non-zero initial condition vectors are now as given below:

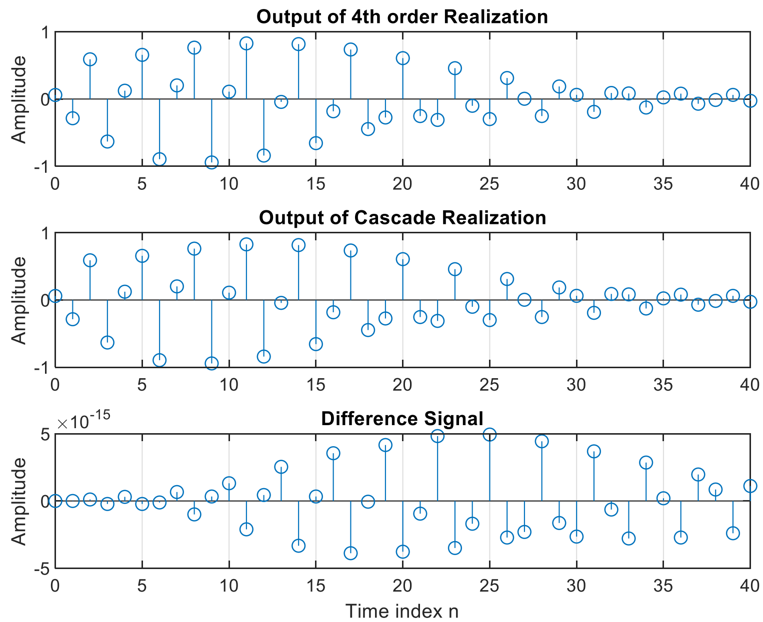


The relation between `y[n]` and `y2[n]` in this case is **not same**

Q2.26 The modified Program P2_6 with the two 2nd-order systems in reverse order and with zero initial conditions is displayed below:

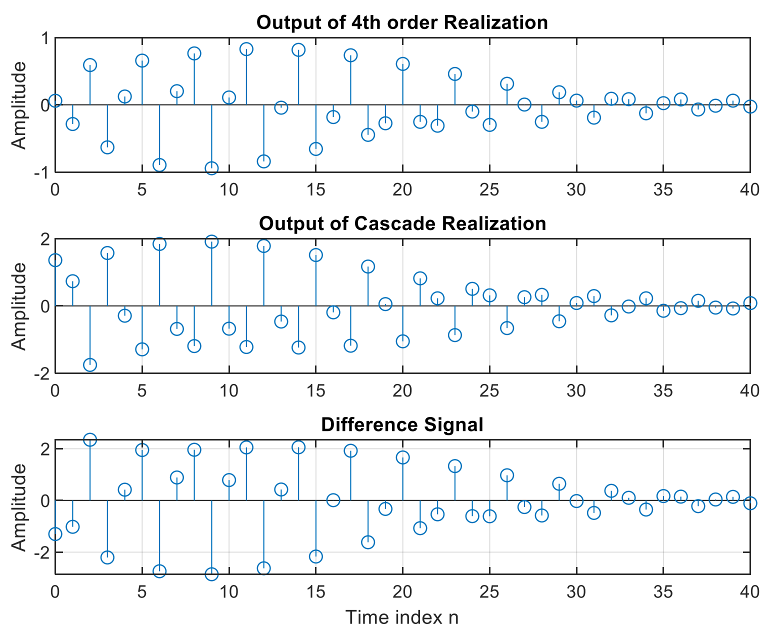
```
% Program Q2.26
% Cascade Realization
clf;
x = [1 zeros(1,40)]; % Generate the input
n = 0:40;
% Coefficients of 4th order system
den = [1 1.6 2.28 1.325 0.68];
num = [0.06 -0.19 0.27 -0.26 0.12];
% Compute the output of 4th order system
y = filter(num,den,x);
% Coefficients of the two 2nd order systems
num1 = [0.3 -0.2 0.4];den1 = [1 0.9 0.8];
num2 = [0.2 -0.5 0.3];den2 = [1 0.7 0.85];
% Output y1[n] of the first stage in the cascade
y1 = filter(num2,den2,x);
% Output y2[n] of the second stage in the cascade
y2 = filter(num1,den1,y1);
% Difference between y[n] and y2[n]
d = y - y2;
% Plot output and difference signals
subplot(3,1,1);
stem(n,y);
ylabel('Amplitude');
title('Output of 4th order Realization'); grid;
subplot(3,1,2);
stem(n,y2)
ylabel('Amplitude');
title('Output of Cascade Realization'); grid;
subplot(3,1,3);
stem(n,d)
xlabel('Time index n');ylabel('Amplitude');
title('Difference Signal'); grid;
```

The sequences generated by running the modified program are sketched below:



The relation between `y[n]` and `y2[n]` in this case is **SAME up to numerical roundoff**

Q2.27 The sequences generated by running the modified Program P2_6 with the two 2nd-order systems in reverse order and with non-zero initial conditions are displayed below:



The relation between `y[n]` and `y2[n]` in this case is **not same**

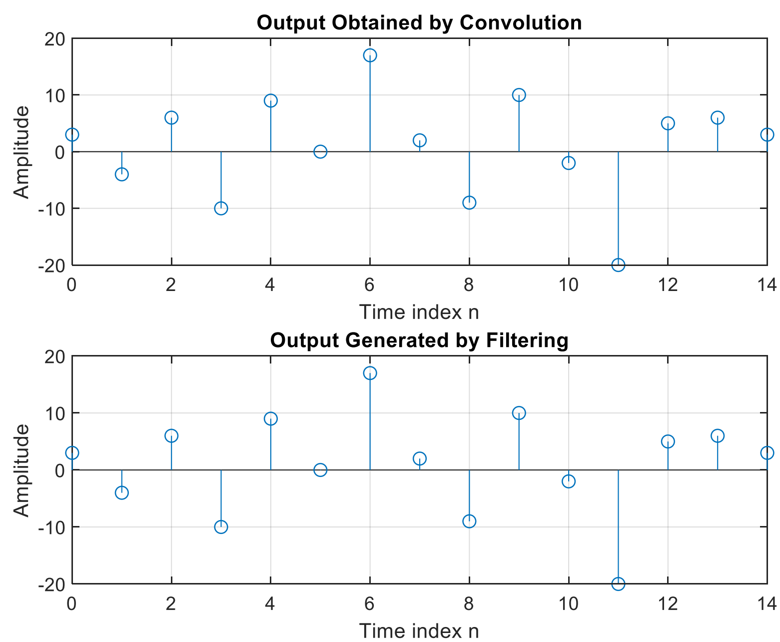
Project 2.7 Convolution

A copy of Program P2_7 is reproduced below:

```
% Program P2_7
clf;
h = [3 2 1 -2 1 0 -4 0 3];  % impulse response
x = [1 -2 3 -4 3 2 1];      % input sequence
y = conv(h,x);
n = 0:14;
subplot(2,1,1);
stem(n,y);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Obtained by Convolution'); grid;
x1 = [x zeros(1,8)];
y1 = filter(h,1,x1);
subplot(2,1,2);
stem(n,y1);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Generated by Filtering'); grid;
```

Answers:

Q2.28 The sequences `y[n]` and `y1[n]` generated by running Program P2_7 are shown below:



The difference between `y[n]` and `y1[n]` is **same**

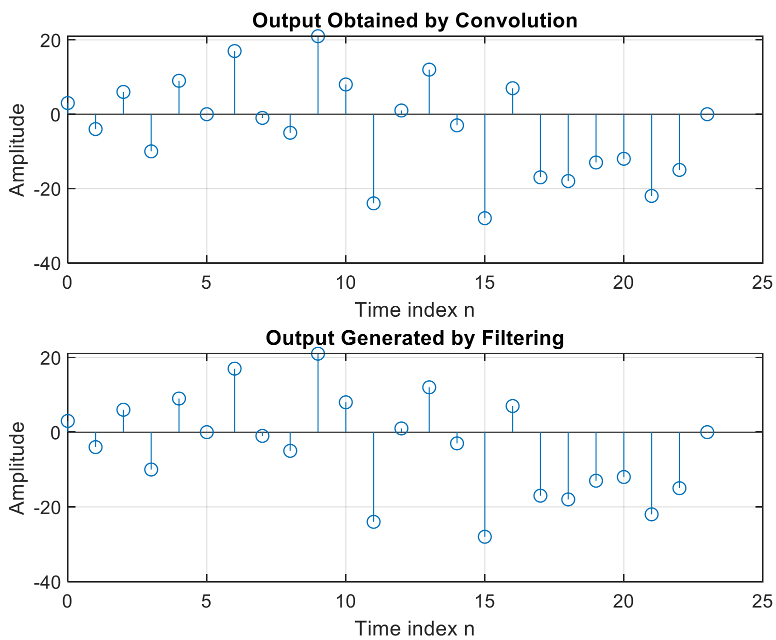
The reason for using `x1[n]` as the input, obtained by zero-padding `x[n]`, for generating `y1[n]` is **For two sequences of length N1 and N2, conv returns the resulting sequence of length N1+N2-1. By contrast, filter accepts an input signal and a system specification. The returned result is the same length as the input signal. Therefore, to obtain directly comparable results from conv and filt, it is necessary**

to supply filt with an input that has been zero padded out to length length(x)+length(h)-1.

Q2.29 The modified Program P2_7 to develop the convolution of a length-15 sequence `h[n]` with a length-10 sequence `x[n]` is indicated below:

```
% Program Q2.29
clf;
h = [3 2 1 -2 1 0 -4 0 3 -1 -2 -3 -4 -5 0]; % impulse
response
x = [1 -2 3 -4 3 2 1 -1 2 3];       % input sequence
y = conv(h,x);
n = 0:length(h)+length(x)-2;
subplot(2,1,1);
stem(n,y);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Obtained by Convolution'); grid;
x1 = [x zeros(1,length(h)-1)];
y1 = filter(h,1,x1);
subplot(2,1,2);
stem(n,y1);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Generated by Filtering'); grid;
```

The sequences `y[n]` and `y1[n]` generated by running modified Program P2_7 are shown below:



The difference between `y[n]` and `y1[n]` is **same**

Project 2.8 Stability of LTI Systems

A copy of Program P2_8 is given below:

```
% Program P2_8
% Stability test based on the sum of the absolute
% values of the impulse response samples
clf;
num = [1 -0.8]; den = [1 1.5  0.9];
N = 200;
h = impz(num,den,N+1);
parsum = 0;
for k = 1:N+1;
    parsum = parsum + abs(h(k));
    if abs(h(k)) < 10^(-6), break, end
end
% Plot the impulse response
n = 0:N;
stem(n,h)
xlabel('Time index n'); ylabel('Amplitude');
% Print the value of abs(h(k))
disp('Value =');disp(abs(h(k)));
```

Answers:

Q2.30 The purpose of the `for` command is **loop to repeat specified number of times**

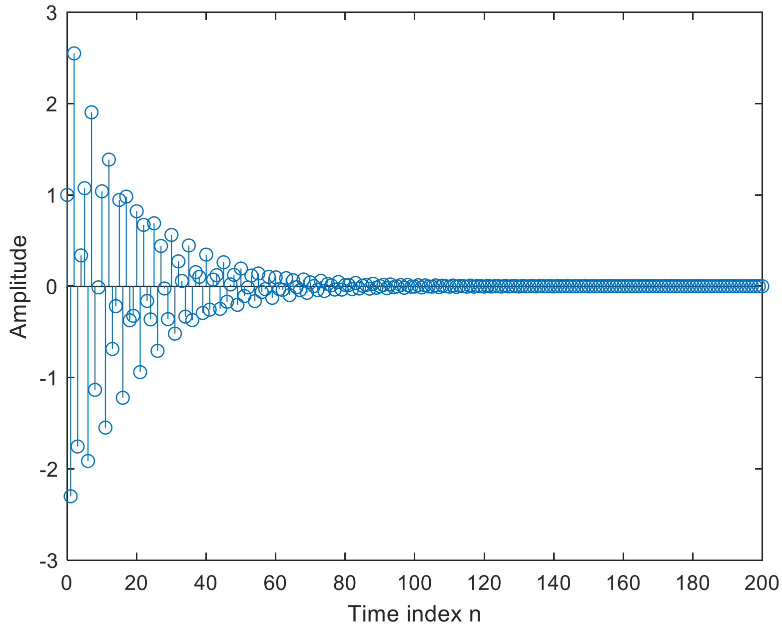
The purpose of the `end` command is **terminate block of code, or indicate last array index**

Q2.31 The purpose of the `break` command is **terminate execution of for or while loop**

Q2.32 The discrete-time system of Program P2_8 is

y[n] + 1.5y[n-1] + 0.9y[n-2] = x[n] – 0.8x[n-1]

The impulse response generated by running Program P2_8 is shown below:



The value of |`h(K)`| here is **1.6761e-05**

From this value and the shape of the impulse response we can conclude that the system is **likely to be stable**

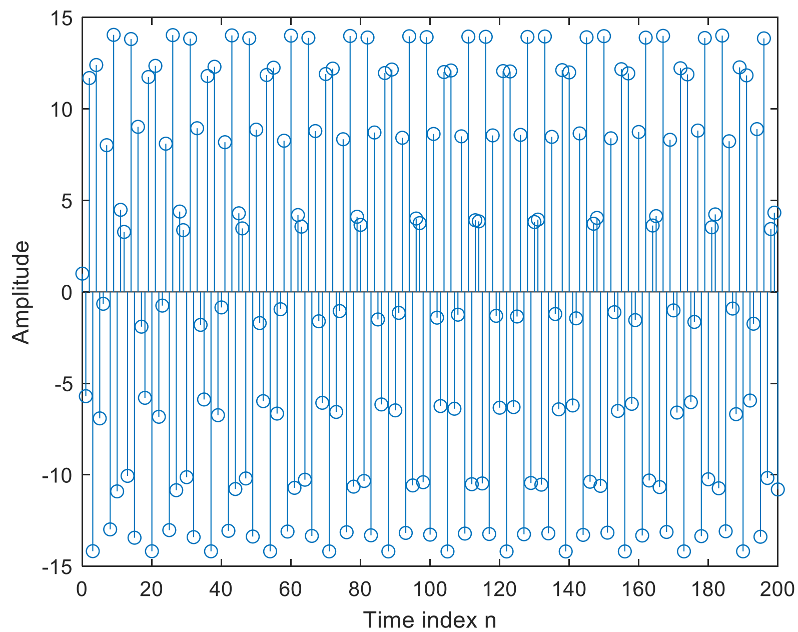
By running Program P2_8 with a larger value of N the new value of |`h(K)`| is **9.1752e-07**

From this value we can conclude that the system is **likely to be stable**

Q2.33 The modified Program P2_8 to simulate the discrete-time system of Q2.33 is given below:

```
% Program P2_8
% Stability test based on the sum of the absolute
% values of the impulse response samples
clf;
num = [1 -4 3]; den = [1 -1.7  1];
N = 200;
h = impz(num,den,N+1);
parsum = 0;
for k = 1:N+1;
    parsum = parsum + abs(h(k));
    if abs(h(k)) < 10^(-6), break, end
end
% Plot the impulse response
n = 0:N;
stem(n,h)
xlabel('Time index n'); ylabel('Amplitude');
% Print the value of abs(h(k))
disp('Value =');disp(abs(h(k)));
```

The impulse response generated by running the modified Program P2_8 is shown below:



The values of |h(K)| here are **2.0321**

From this value and the shape of the impulse response we can conclude that the system is **almost unstable.**

Project 2.9 Illustration of the Filtering Concept

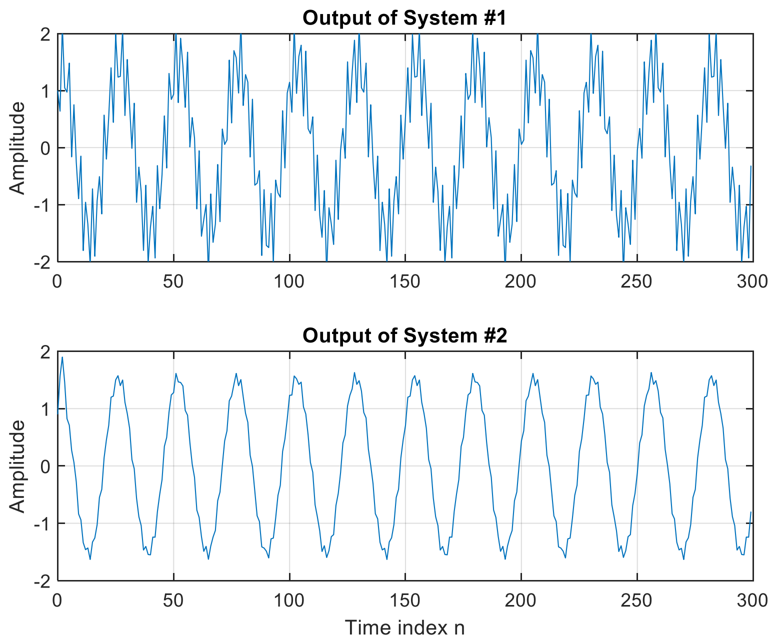
A copy of Program P2_9 is given below:

```
% Program P2_9
% Generate the input sequence
clf;
n = 0:299;
x1 = cos(2*pi*10*n/256);
x2 = cos(2*pi*100*n/256);
x = x1+x2;
% Compute the output sequences
num1 = [0.5 0.27 0.77];
y1 = filter(num1,1,x); % Output of System #1
den2 = [1 -0.53 0.46];
num2 = [0.45 0.5 0.45];
y2 = filter(num2,den2,x); % Output of System #2
% Plot the output sequences
subplot(2,1,1);
plot(n,y1);axis([0 300 -2 2]);
ylabel('Amplitude');
title('Output of System #1'); grid;
subplot(2,1,2);
```

```
plot(n,y2);axis([0 300 -2 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Output of System #2'); grid;
```

Answers:

Q2.34 The output sequences generated by this program are shown below:

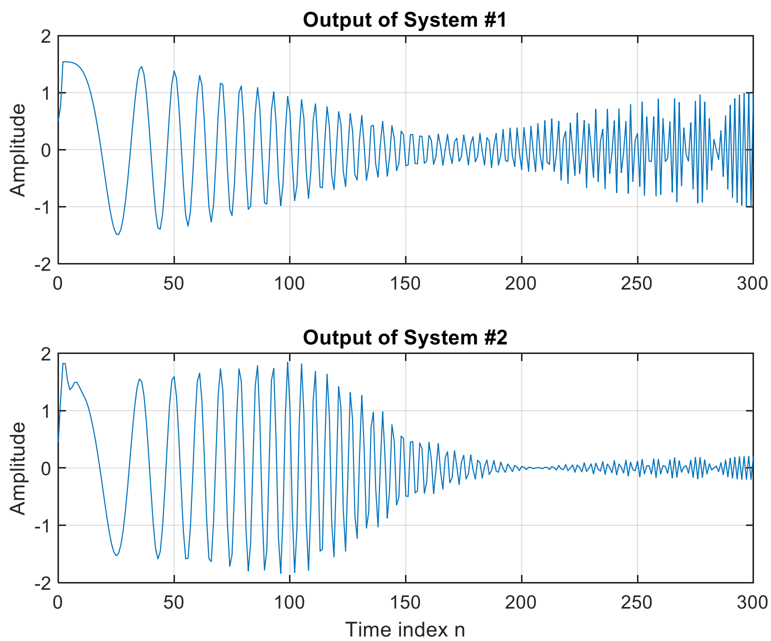


The filter with better characteristics for the suppression of the high frequency component of the input signal `x[n]` is **System #2**

Q2.35 The required modifications to Program P2_9 by changing the input sequence to a swept sinusoidal sequence (length 301, minimum frequency 0, and maximum frequency 0.5) are listed below along with the output sequences generated by the modified program:

```
% Program Q2.35
% Generate the input sequence
clf;
n = 0:300;
a = pi/600;
b = 0;
arg = a*n.*n + b*n;
x = cos(arg);
% Compute the output sequences
num1 = [0.5 0.27 0.77];
y1 = filter(num1,1,x); % Output of System #1
den2 = [1 -0.53 0.46];
num2 = [0.45 0.5 0.45];
y2 = filter(num2,den2,x); % Output of System #2
% Plot the output sequences
subplot(2,1,1);
plot(n,y1);axis([0 300 -2 2]);
```

```
ylabel('Amplitude');
title('Output of System #1'); grid;
subplot(2,1,2);
plot(n,y2);axis([0 300 -2 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Output of System #2'); grid;
```



The filter with better characteristics for the suppression of the high frequency component of the input signal x[n] is **System #2**

Date: 26/9/2024 **Signature:** Nguyễn Đình Khánh Vy