CIRCULAR CONVOLUTION

MATLAB CODE:

```
x=input('Enter x[n]');
h=input('Enter h[n]');
l1=length(x);
l2=length(h);
N=max(l1,l2);
X=[x zeros(1,(N-l1))];
H=[h zeros(1,(N-l2))];

%using Inbuilt Function
Z=cconv(X,H,N);
disp(Z);

%using the formula
for n=1:N
    y(n)=0;
    for k=1:N
        y(n)=y(n)+X(k).*H(mod((n-k),N)+1);
    end
end

%plots
n=0:(N-1);

subplot(3,1,1);
stem(n,X);
xlabel('time');
ylabel('Amp');
title('X[n]');

subplot(3,1,2);
stem(n,H);
xlabel('time');
ylabel('Amp');
title('H[n]');

subplot(3,1,3);
stem(n,y);
xlabel('time');
ylabel('Amp');
title('Y[n] convolved sequence');
```

TEST CASES

1.X[n]=[1 2 3 4];

H[n]=[1 2 3 4];

COMMAND WINDOW OUTPUT

>> exp2circular

Enter x[n][1 2 3 4]

Enter h[n][1 2 3 4]

26   28   26   20

2.X[n]=[1 2 3 4];

H[n]=[2 3 4];

<u>Command window output</u>

>> exp2circular

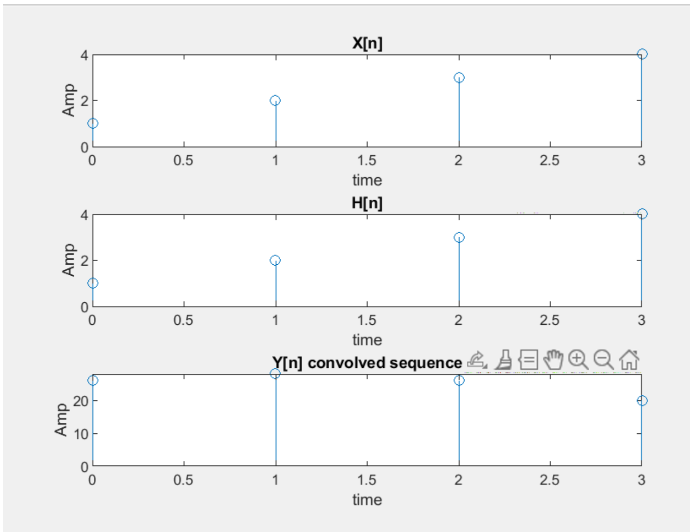
Enter x[n][1 2 3 4]

Enter h[n][2 3 4]

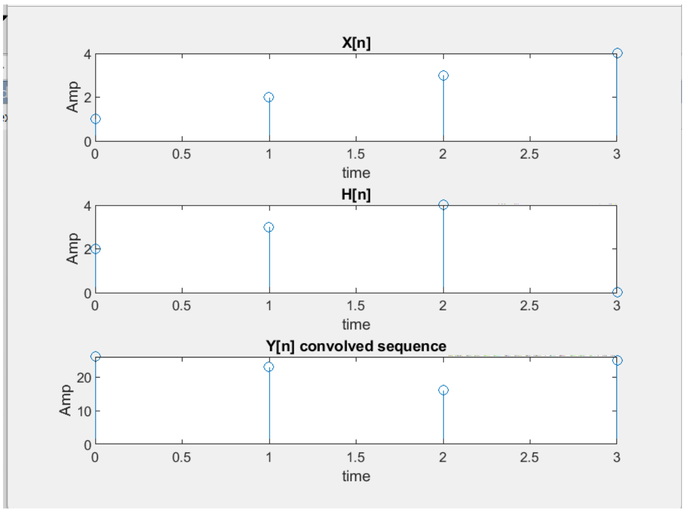
26   23   16   25

PLOTS

1.



2.



Theoretical Calculation:

lab 2

Circular Convolution

(1) $x(n) = [1, 2, 3, 4]$

$h[n] = [1, 2, 3, 4] = y'(n)$

$\quad\quad\;\; 0 \;\; 1 \;\; 2 \;\; 3$

$$y(m) = \sum_{n=0}^{N-1} x(n)\, y'((m-n))_N$$

$y(0) = x(0)\, y'((0))_4 + x(1)\, y'((-1))_4 + x(2)\, y'((-2))_4 + x(3)\, y'((-3))_4$

$= 1 \times 1 + 2 \times 4 + 3 \times 3 + 4 \times 2$

$= 26.$

$y(1) = x(0)\, y'(1) + x(1)\, y'((0))_4 + x(2)\, y'(3) + x(3)\, y'(2)$

$= 1 \times 2 + 2 \times 1 + 3 \times 4 + 4 \times 3.$

$= 28$

$y(2) = x(0)\, y'(2) + x(1) \cdot y'(1) + x(2)\, y'(0) + x(3)\, y'(3)$

$= 1 \times 3 + 2 \times 2 + 3 \times 1 + 4 \times 4$

$= 26$

$y(3) = x(0)\, y'(3) + x(1)\, y'(2) + x(2)\, y'(1) + x(3)\, y'(0)$

$= 1 \times 4 + 2 \times 3 + 3 \times 2 \quad 4 \times 1$

$= 20.$

$\quad\quad\;\; 0 \;\; 1 \;\; 2 \;\; 3$

(2) $x(n) = [1\ 2\ 3\ 4]$ $\quad l_1 = 4$

$h[n] = [2\ 3\ 4]$ $\quad l_2 = 3.$

$\therefore$ padd $h[n]$ with $l_1 - l_2$ zeros $= 1.$

$\therefore h[n] = [2\ 3\ 4\ 0] = y'(n)$

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$$y(m) = \sum_{n=0}^{N-1} x(n)\, h((m-n))_N.$$

$$y(0) = x(0)\,y'(0) + x(1)\,y'(3) + x(2)\,y'(2) + x(3)\,y'(1)$$
$$= 1\times2 + 2\times0 + 3\times4 + 4\times3$$
$$= 2+12+12$$
$$= 26.$$

$$y(1) = x(0)\,y'(1) + x(1)\,y'(0) + x(2)\,y'(3) + x(3)\,y'(2)$$
$$= 1\times3 + 2\times2 + 3\times0 + 4\times4$$
$$= 23.$$

$$y(2) = x(0)\,y'(2) + x(1)\,y'(1) + x(2)\,y'(0) + x(3)\,y'(3)$$
$$= 1\times4 + 2\times3 + 3\times2 + 4\times0$$
$$= 16.$$

$$y(3) = x(0)\cdot y'(3) + x(1)\,y'(2) + x(2)\cdot y'(1) + x(3)\,y'(0)$$
$$= 1\times0 + 2\times4 + 3\times3 + 4\times2$$
$$= 25.$$

Linear convolution

MATLAB CODE:

```
x=input('Enter x[n]:');
nx=input('Enter x[n] time indices :');
h=input('Enter h[n]:');
nh=input("Enter h[n] time indices:");

[y,ny]=findconv(x,nx,h,nh); %findconv function present in findconv.m

subplot(3,1,1);
stem(nx,x);
```

```
xlabel('time');
ylabel('Amp');
title('X[n]');

subplot(3,1,2);
stem(nh,h);
xlabel('time');
ylabel('Amp');
title('H[n]');

subplot(3,1,3);
stem(ny,y);
xlabel('time');
ylabel('Amp');
title('Y[n]');

disp(y);
disp(ny);
```

findconv.m

```
function [y,ny]=findconv(x,nx,h,nh)
    nybegin=nx(1)+nh(1);
    nyend=nx(length(nx))+nh(length(nh));
    ny=nybegin:nyend;
    y=conv(x,h);
    y=calcconv(x,h);
end
```

calcconv.m

```
function [y]=calcconv(x,h)
    l1=length(x);
    l2=length(h);
    N=l1+l2-1;
    for n=1:N
        y(n)=0
        for k=1:l1
            if(n-k+1>=1 && n-k+1<=l2)
                y(n)=y(n)+x(k).*h(n-k+1)
            end
        end
    end
end
```

TEST CASES

1.X[n]=[1 2 3 4]

H[n]=[1 2 3 4]

Command Terminal Output:

```
>> exp2linear
Enter x[n]:[1 2 3 4]
Enter x[n] time indices :[0 1 2 3]
Enter h[n]:[1 2 3 4]
Enter h[n] time indices:[0 1 2 3]
```

```
y =

     1     4    10    20    25    24    16
```

2. .X[n]=[1 2 3]

H[n]=[1 2 3 4]

Command Terminal Output:

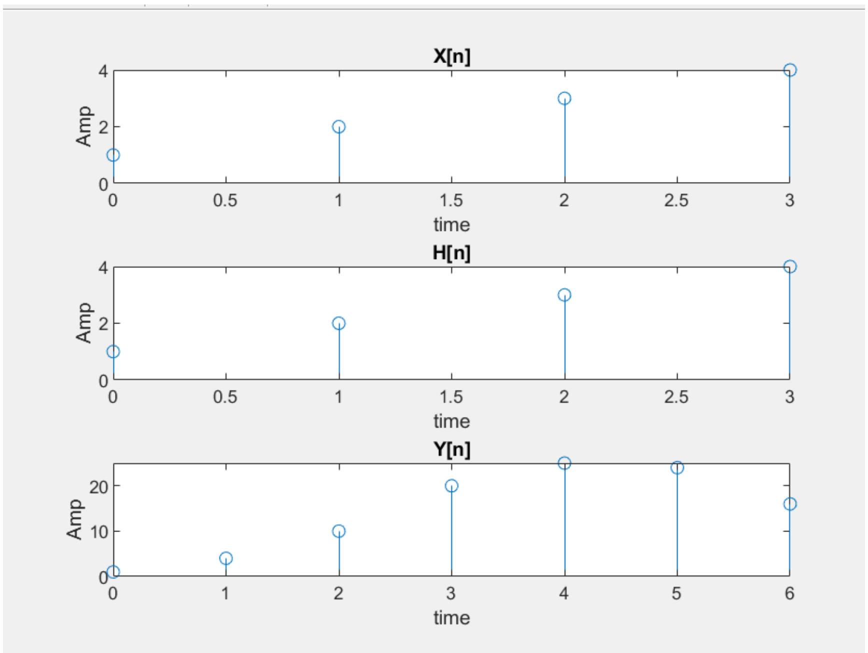
```
>> exp2linear
Enter x[n]:[1 2 3]
Enter x[n] time indices :[0 1 2]
Enter h[n]:[1 2 3 4]
Enter h[n] time indices:[-2 -1 0 1]
```

```
y =

     1     4    10    16    17    12
```

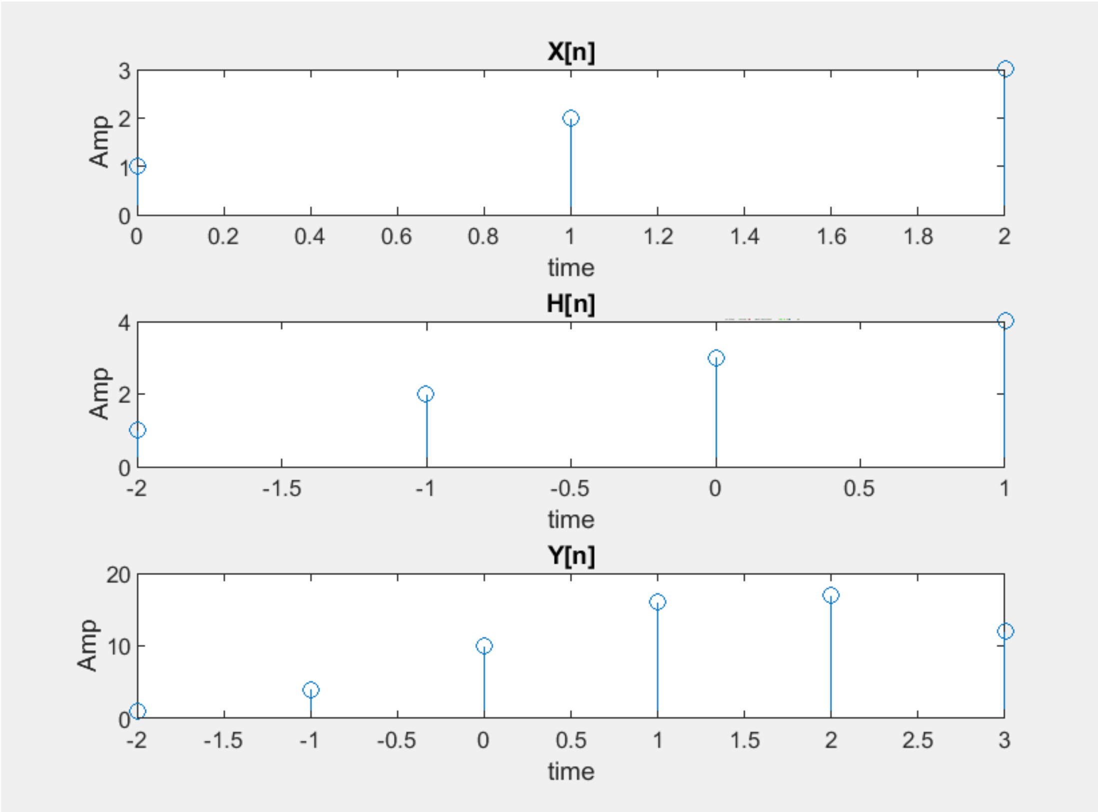
PLOTS

1.



:

2.



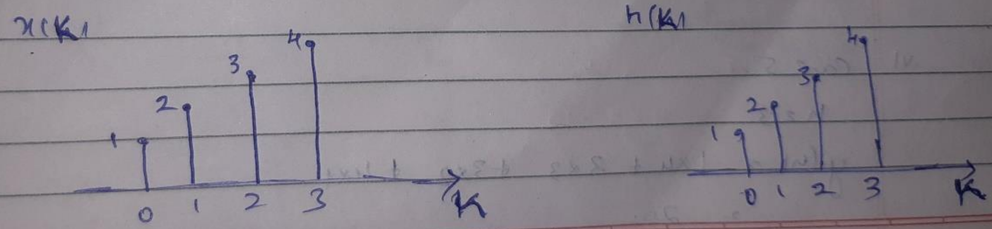
Theoretical Calculation:

- Linear convolution

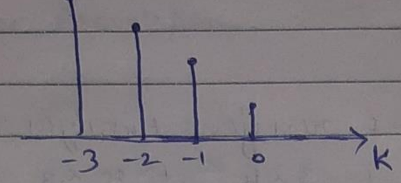
1. $x(n) = [1, 2, 3, 4]$

$h[n] = [1, 2, 3, 4]$.

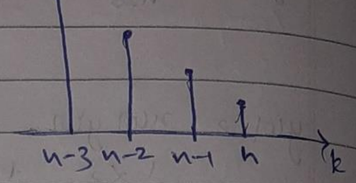
$$y(n) = \sum_{k=0}^{3} x(k) \cdot h(n-k).$$

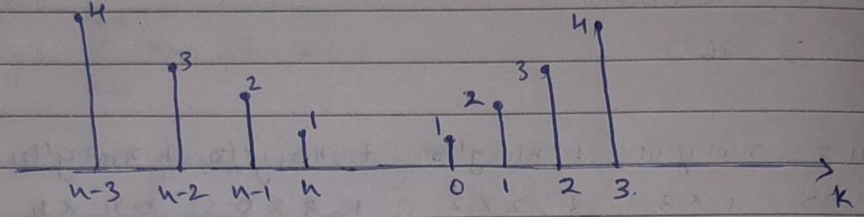


$h(-k)$



$h(n-k)$





case 1:

i if $n<0$. $\longrightarrow$ No overlap.

$y(n)=0$.

ii Case 2:

$n=0$.

$y(n) = 1\times1 = 1$

iii Case 3:

$n=1$

$y(n) = 1\times2 + 2\times1$

$= 4$.

iv Case 4:

$n=2$

$y(n) = 1\times3 + 2\times2 + 3\times1$

$= 10$

.v Case 5:

$n=3$

$y(n) = 1\times4 + 2\times3 + 3\times2 + 4\times1$

$= 20$

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vi Case 6:

$n-3 = 3 \longrightarrow n = 4.$

$y(n) = 2\times 4 + 3\times 3 + 4\times 2$

$= 25$

vii Case 7:

$n-2 = 3 \longrightarrow n = 5.$

$y(n) = 3\times 4 + 4\times 3$

$= 24.$

$\therefore y(n) = [\underset{\uparrow}{1} \ \ 4 \ \ 10 \ \ 20 \ \ 25 \ \ 24 \ \ 16]$

viii Case 8:

$n-3 = 3 \longrightarrow n = 6.$

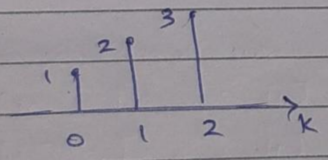
$y(n) = 4\times 4 = 16.$

② $x(n) = [1, 2, 3]$

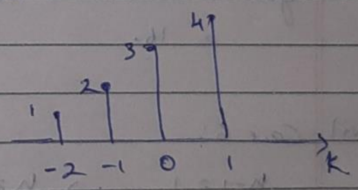
$h[n] = [1, 2, \underset{\uparrow}{3}, 4]$

$y(n) = x(n) * h(n)$

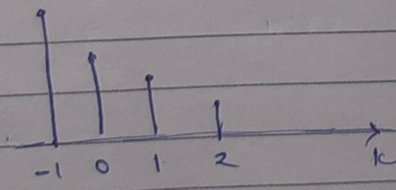
x(k)



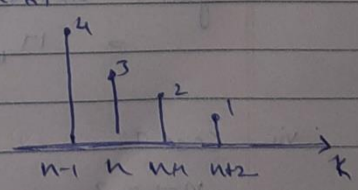
h(k)

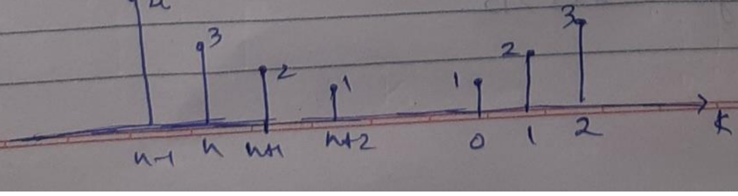


h(-k)



h(n-k)





Case 1:

i) $n+2<0 \longrightarrow n<-2$ no overlap.

$y(n)=0.$

ii) Case 2:

$n+2=0 \longrightarrow n=-2$

$y(n)=1.$

iii) Case 3:

$n+2=1 \longrightarrow n=-1.$

$y(n)=2\times1+2\times1=4.$

iv) Case 4:

$n+2=2 \longrightarrow n=0.$

$y(n)=3\times1+2\times2+3\times1$

$=10.$

v) Case 5:

$n-1=0.$

$n=1.$

$y(n)=4\times1+3\times2+2\times3$

$=16.$

$\therefore y(n)=(1, 4, \underset{\uparrow}{10}, 16, 17, 12)$

vi) Case 6:

$n-1=1 \longrightarrow n=2$

$y(n)=4\times2+3\times3$

$=17$

vii) Case 7:

$n-1=2. \longrightarrow n=3.$

$y(n)=4\times3=12.$