1 Linear Convolution

Write a matlab code for linear convolution of two signals. Then

1. Generate the causal signals

$$
\begin{aligned}
x_1[n] &= \{\underset{\uparrow}{-2},\ 2,\ 3,\ 1,\ 12\} \\
x_2[n] &= \{\underset{\uparrow}{1}, -1, 4, -2\} \\
h[n] &= \{\underset{\uparrow}{3},\ -2,\ -5,\ 1,\ -4\}
\end{aligned}
$$

Now, determine the output of the given systems

$$
\begin{aligned}
y_1[n] &= (x_1[n] + x_2[n]) * h[n] \\
y_2[n] &= x_1[n] * h[n] + x_2[n] * h[n]
\end{aligned}
$$

(a) Perform the calculations using your matlab code and verify the results using the inbuilt function *conv* and on-paper calculations.

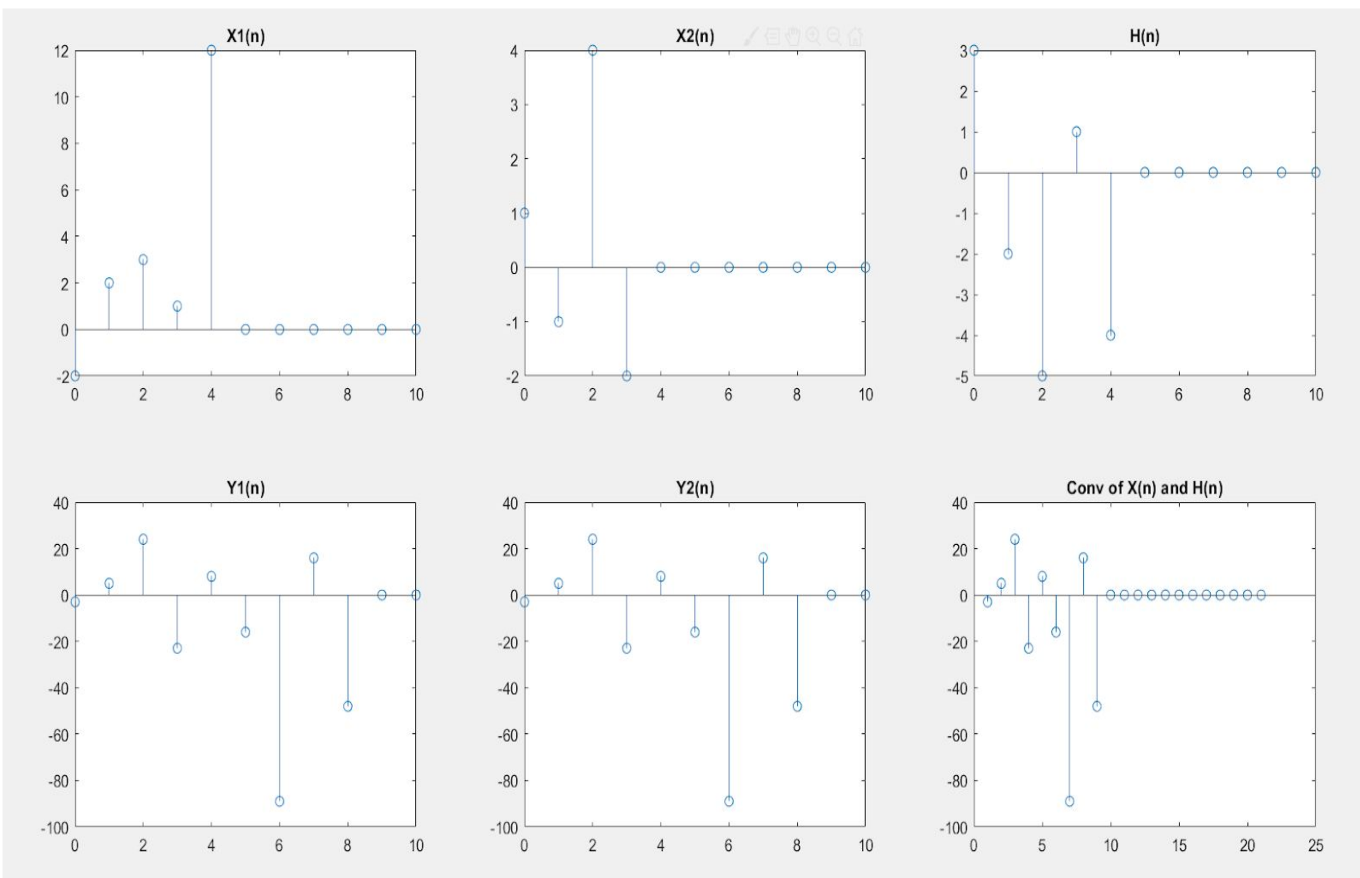
(b) Verify if the outputs $y_1[n]$ and $y_2[n]$ are identical or not.

(c) Using the *stem* function, plot the signals $x_1[n]$, $x_2[n]$, $h[n]$, $y_1[n]$ and $y_2[n]$.

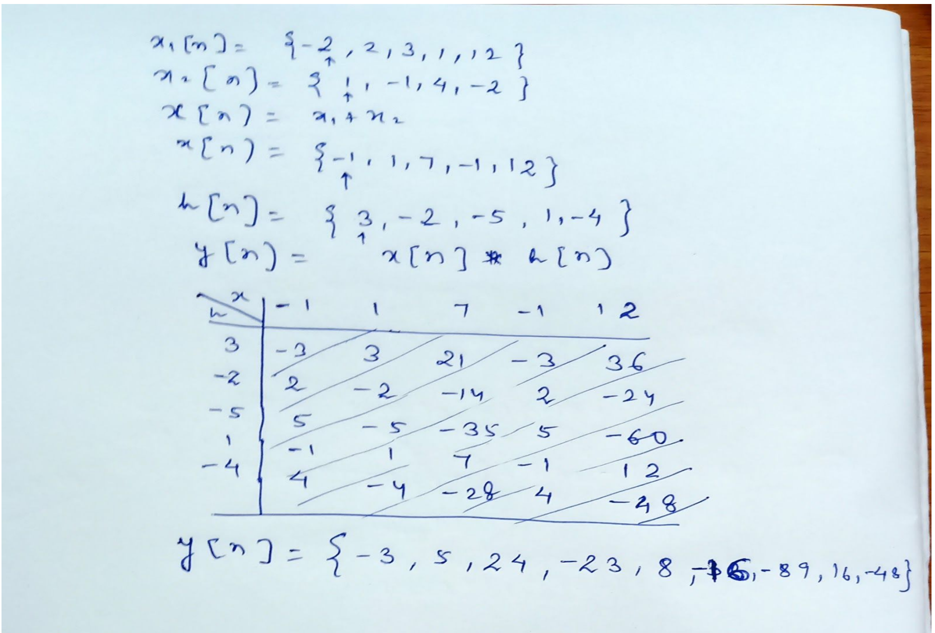
```
n=0:10;
x1=zeros(size(n));
x2=zeros(size(n));
h=x1;
y1=h;
x1(n==0)=-2;
x1(n==1)=2;
x1(n==2)=3;
x1(n==3)=1;
x1(n==4)=12;
x1(n==5)=0;
x1(n==6)=0;
x1(n==7)=0;
x1(n==8)=0;
x2(n==0)=1;
x2(n==1)=-1;
x2(n==2)=4;
x2(n==3)=-2;
```

```
x2(n==4)=0;
x2(n==5)=0;
x2(n==6)=0;
x2(n==7)=0;
x2(n==8)=0;
h(n==0)=3;
h(n==1)=-2;
h(n==2)=-5;
h(n==3)=1;
h(n==4)=-4;
h(n==5)=0;
h(n==6)=0;
h(n==7)=0;
x=x1+x2;
y1=zeros(size(n));
for l=1:10
        y1(l)=0;
        for k=1:l
        y1(l)=y1(l)+h(k).*x(l-k+1);
        end
end
ya=zeros(size(n));
for l=1:10
        ya(l)=0;
        for k=1:l
        ya(l)=ya(l)+h(k).*x1(l-k+1);
        end
end
yb=zeros(size(n));
for l=1:10
        yb(l)=0;
        for k=1:l
        yb(l)=yb(l)+h(k).*x2(l-k+1);
        end
end
y2=ya+yb;
z=conv(x,h);
subplot(231);
stem(n,x1);
title('X1(n)');
subplot(232);
stem(n,x2);
title('X2(n)');
```

```
subplot(233);
stem(n,h);
title('H(n)');
subplot(234);
stem(n,y1);
title('Y1(n)');
subplot(235)
stem(n,y2);
title('Y2(n)');
subplot(236)
stem(z);
title('Conv of X(n) and H(n)');
```



Y1(n)=Y2(n)=Conv of X(n) and H(n)={-3, 5, 24, -23, 8, -16, -89, 16, -48}



$x_1[n] = \{\underset{\uparrow}{-2}, 2, 3, 1, 12\}$
$x_2[n] = \{\underset{\uparrow}{1}, -1, 4, -2\}$
$x[n] = x_1 + x_2$
$x[n] = \{\underset{\uparrow}{-1}, 1, 7, -1, 12\}$
$h[n] = \{\underset{\uparrow}{3}, -2, -5, 1, -4\}$
$y[n] = x[n] * h[n]$

h \ x	-1	1	7	-1	12
3	-3	3	21	-3	36
-2	2	-2	-14	2	-24
-5	5	-5	-35	5	-60
1	-1	1	7	-1	12
-4	4	-4	-28	4	-48

$y[n] = \{-3, 5, 24, -23, 8, -6, -89, 16, -48\}$

2. Next, generate the translated signals

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

Now, determine the output of the given system

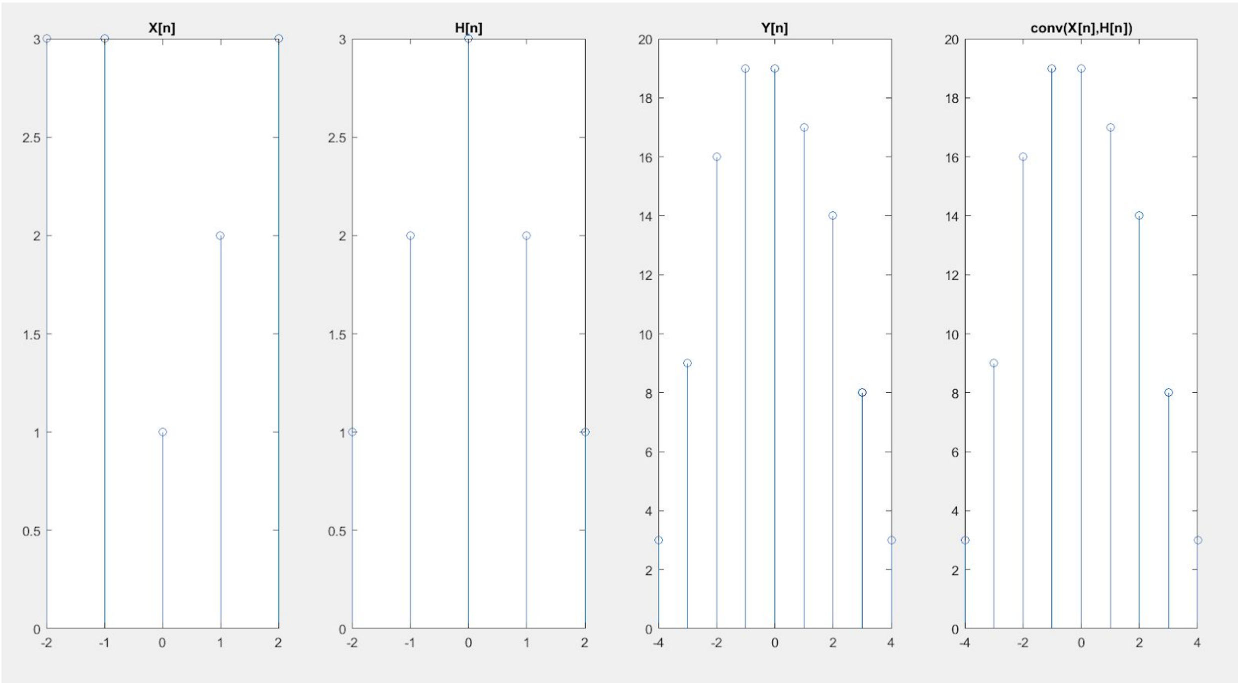
$$y[n] = x[n] * h[n]$$

(a) Perform the calculations using your matlab code and verify the results using the inbuilt function *conv* and on-paper calculations.

(b) Using the *stem* function, plot the signals $x[n]$, $h[n]$, and $y[n]$.

```
N=-2:1:2;
x=X(N);
h=H(N);
l=size(x')+size(h')-1;
```

```
he=zeros(l);
xe=zeros(l);
he(1:size(h'))=h;
xe(1:size(x'))=x;
y=zeros(l);
for n=1:1:l
            y(n)=0;
            for k=1:1:n
            y(n)=y(n)+he(k).*xe(n-k+1);
            end
end
y=y'
N1=-4:1:-4+l-1;
subplot(141);
stem(N,x);
title('X[n]');
subplot(142);
stem(N,h);
title('H[n]');
subplot(143);
stem(N1,y);
title('Y[n]');
co=conv(x,h);
subplot(144);
stem(N1,co);
title('conv(X[n],H[n])');
function a=X(n)
a=zeros(size(n));
a(n==-2)=3;
a(n==-1)=3;
a(n==0)=1;
a(n==1)=2;
a(n==2)=3;
end
function a=H(n)
a=zeros(size(n));
a(n==-2)=1;
a(n==-1)=2;
a(n==0)=3;
a(n==1)=2;
a(n==2)=1;
end
```



Y2(n)=Conv of X(n) and H(n)={3, 9, 16, 19, 19, 17,14, 8, 3}

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

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

$y[n] = x[n] * h[n]$

h \ x	3	3	1	2	3
1	3	3	1	2	3
2	6	6	2	4	6
3	9	9	3	6	9
2	6	6	2	4	6
1	3	3	1	2	3

$y[n] = \{3, 9, 16, 19, \underset{\uparrow}{19}, 17, 14, 8, 3\}$

3. Next generate the signals

$$x[n] = \{\underset{\uparrow}{2},\ -1,\ 4,\ -7,\ 5\}$$
$$h[n] = \{\underset{\uparrow}{2},\ 4,\ 2,\ 4,\ 1\}$$

Now, compute the ouput of the given systems

$$y_1[n] = x[n] * h[-n]$$
$$y_2[n] = x[3-n] * h[n]$$

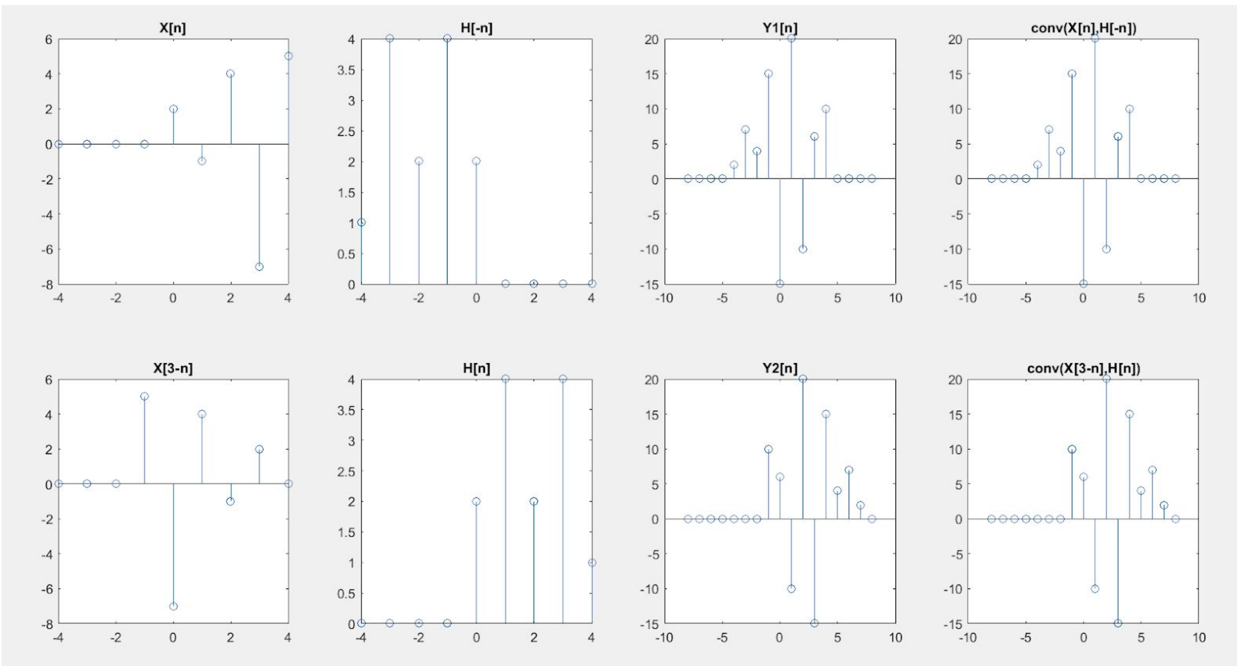
(a) Perform the calculations using your matlab code and verify the results using the inbuilt function *conv* and on-paper calculations.

(b) Using the *stem* function, plot the signals $x[n]$, $h[n]$, $y_1[n]$ and $y_2[n]$.

```
N=-4:1:4;
x1=X(N,1,0);
h1=H(N,-1,0);
x2=X(N,-1,3);
h2=H(N,1,0);
l=size(x1')+size(h1')-1;
he=zeros(l);
xe=zeros(l);
he(1:size(h1'))=h1
xe(1:size(x1'))=x1
y1=zeros(l);
y2=zeros(l);
for n=1:1:l
        y1(n)=0;
        for k=1:1:n
        y1(n)=y1(n)+he(k).*xe(n-k+1);
        end
end
y1=y1'
xe(12)
he(1:size(h2'))=h2;
xe(1:size(x2'))=x2;
for n=1:1:l
```

```
        y2(n)=0;
        for k=1:1:n
        y2(n)=y2(n)+he(k).*xe(n-k+1);
        end
end
y2=y2'
N1=-8:1:l-1-8;
subplot(2,4,1);
stem(N,x1);
title('X[n]');
subplot(2,4,2);
stem(N,h1);
title('H[-n]');
subplot(2,4,3);
stem(N1,y1);
title('Y1[n]');
co1=conv(x1,h1);
subplot(2,4,4);
stem(N1,co1);
title('conv(X[n],H[-n])');
subplot(2,4,5);
stem(N,x2);
title('X[3-n]');
subplot(2,4,6);
stem(N,h2);
title('H[n]');
subplot(2,4,7);
stem(N1,y2);
title('Y2[n]');
co2=conv(x2,h2);
subplot(2,4,8);
stem(N1,co2);
title('conv(X[3-n],H[n])');
function a=X(n,c,d)
a=zeros(size(n));
a(n==d)=2;
a(n==c+d)=-1;
a(n==(2*c)+d)=4;
a(n==(3*c)+d)=-7;
a(n==(4*c)+d)=5;
end
function a=H(n,c,d)
a=zeros(size(n));
```

```
a(n==d)=2;
a(n==c+d)=4;
a(n==(2*c)+d)=2;
a(n==(3*c)+d)=4;
a(n==(4*c)+d)=1;
end
```



Y1(n)=Conv of X(n) and H(-n)={0, 0, 0, 0, 2, 7, 4, 15, -15, 20, -10, 6, 10, 0, 0}
Y2(n)=Conv of X(3-n) and H(n)={0, 0, 0, 0, 0, 0, 0, 10, 6, -10, 20, -15, 15, 4, 7, 2, 0}

$$x[n] = \{\underset{\uparrow}{2}, -1, 4, -7, 5\}$$

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

$$x[3-n] = \{5, \underset{\uparrow}{-7}, 4, -1, 2\}$$

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

$$y_2[n] = x[n] * h[-n]$$

$$= \sum_{k=-\infty}^{\infty} x[k]\, h[-(n-k)]$$

$$= \sum_{0}^{\infty} x[n]\, h[-n+k]$$

$$y_1[n] = x[0]\, h[-n] + x[1]\, h[-n-1] + \cdots x[4]\, h[-n-4]$$

$$= 2h[-n] - h[-n+1] + 4h[-n+2] +$$

$$h[-n+3] + 3h[-n+4]$$

$$y_1[n] = \{0, 0, 0, 0, 2, 7, 4, 15, \underset{\uparrow}{-15}, 20, -10, 6, 1\}$$

$$y_2[n] = x[3-n] * h[n] = \sum_{k=-\infty}^{\infty} x[3-n+k]\, h[k]$$

$$y_2[n] = 2x[3-n] + 4x[4-n] + 2x[5-n] +$$

$$4x[6-n] + x[7-n]$$

$$y_2 = \{0, 0, 0, 0, 0, 0, 0, 10, \underset{\uparrow}{6}, -10, 20, -15, 15,$$

$$4, 7, 2, 0\}$$