

Experiment - 3 : Convolution

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- L21+L22

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3.1 $x(n) = u(n-1) - u(n-6)$

$$h(n) = \text{tri} \left[\frac{n-6}{4} \right]$$

Find the convolution sum,

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

3.2 $x(n) = u(n) - u(n-4)$

$$y(n) = nu(n) - 2(n-4)u(n-4) + (n-8)u(n-8)$$

Make stem plots of the following convolutions.

i] $x(n) * x(n)$

ii] $x(n) * x(n) * x(n)$

iii] $x(n) * y(n)$

iv] $y(n) * d(n)$

v] $y(n) * y(n)$

vi] Is there any relationship between (i) and $y(n)$? Compare (i), (ii) and (iii), what happens when you repeatedly convolve the signal with itself?

3.3 Make stem plots of the following signals, decide range of 'n'

$$x(n) = 3\delta(n+2) - \delta(n-1) + 2\delta(n-2)$$

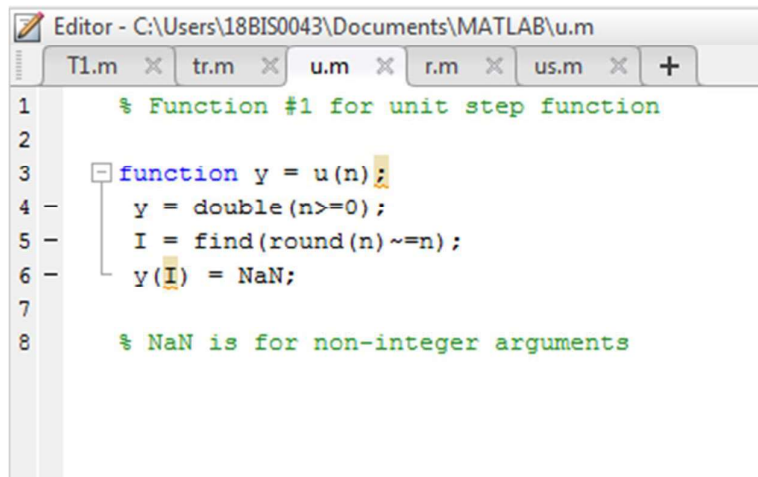
$$h(n) = u(n+4) - u(n-3)$$

- i] Stem plot of $x(n) * h(n)$
- ii] Plot signals by hand

Experiment – 3: Convolution

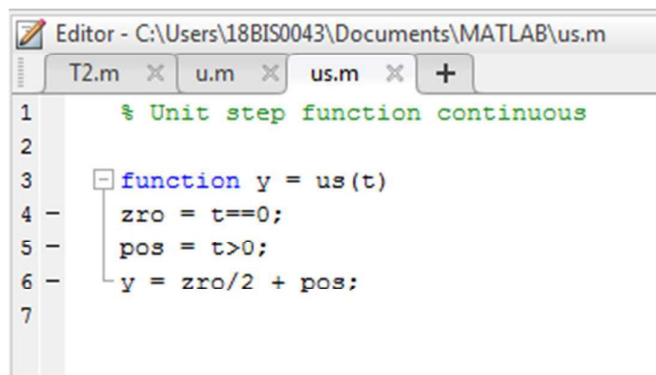
3.1.

Unit Step function 'u':



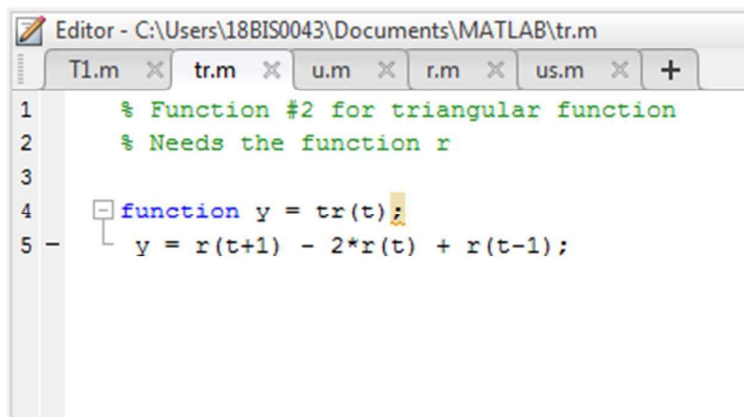
```
Editor - C:\Users\18BIS0043\Documents\MATLAB\u.m
T1.m x tr.m x u.m x r.m x us.m x +
1      % Function #1 for unit step function
2
3      function y = u(n);
4      -   y = double(n>=0);
5      -   I = find(round(n)~=n);
6      -   y(I) = NaN;
7
8      % NaN is for non-integer arguments
```

Unit Step functions 2 'us':



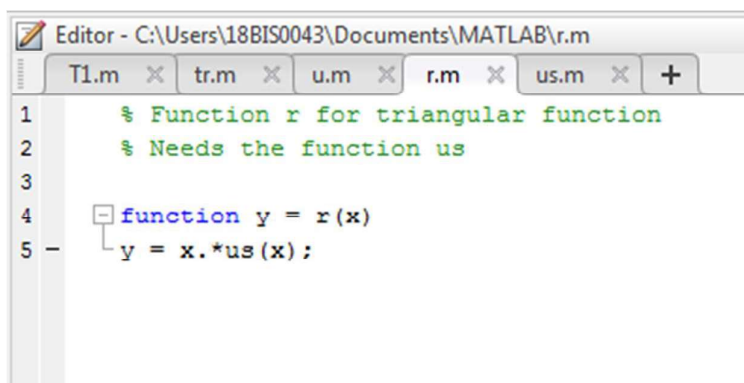
```
Editor - C:\Users\18BIS0043\Documents\MATLAB\us.m
T2.m x u.m x us.m x +
1      % Unit step function continuous
2
3      function y = us(t)
4      -   zro = t==0;
5      -   pos = t>0;
6      -   y = zro/2 + pos;
7
```

Triangular function 'tr'



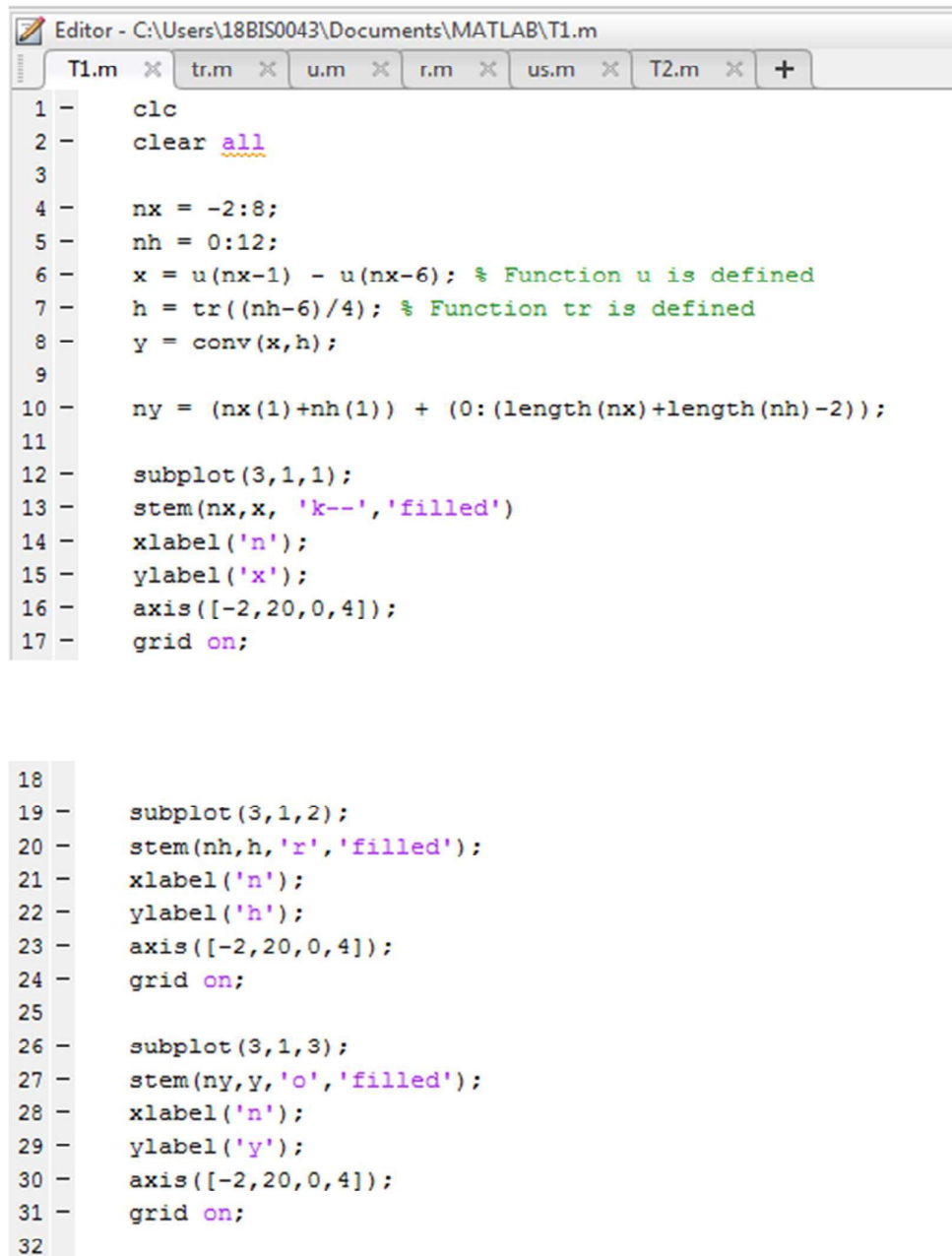
```
Editor - C:\Users\18BIS0043\Documents\MATLAB\tr.m
Tl.m x tr.m x u.m x r.m x us.m x +
1      % Function #2 for triangular function
2      % Needs the function r
3
4      function y = tr(t);
5      y = r(t+1) - 2*r(t) + r(t-1);
```

The 'ramp' function is a part of the triangular function and this function needs the continuous unit step function named 'us'



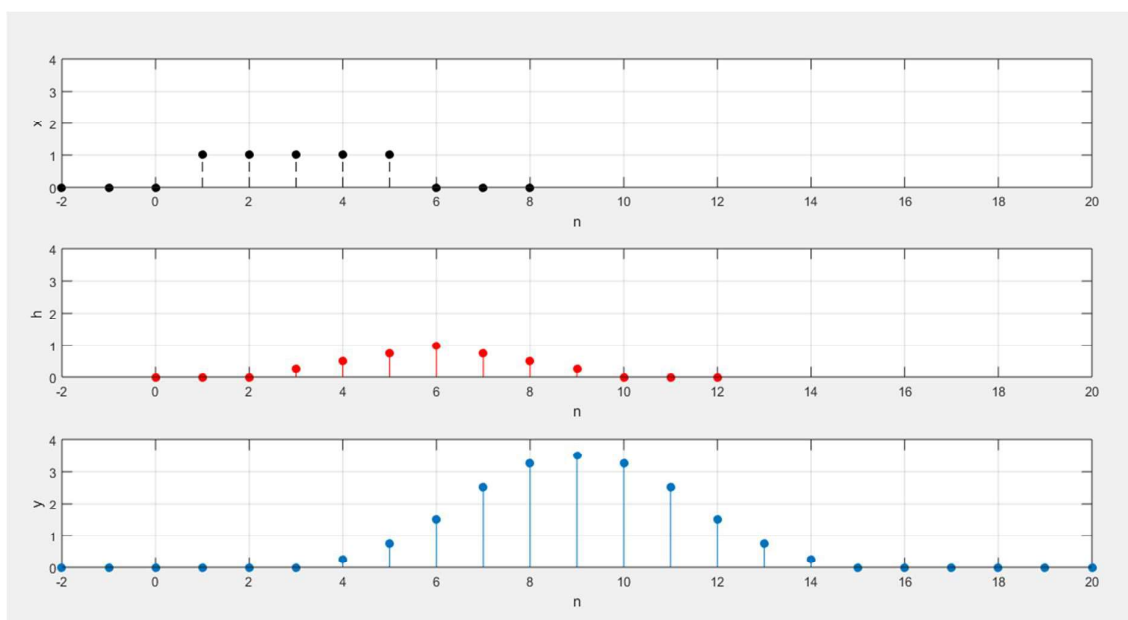
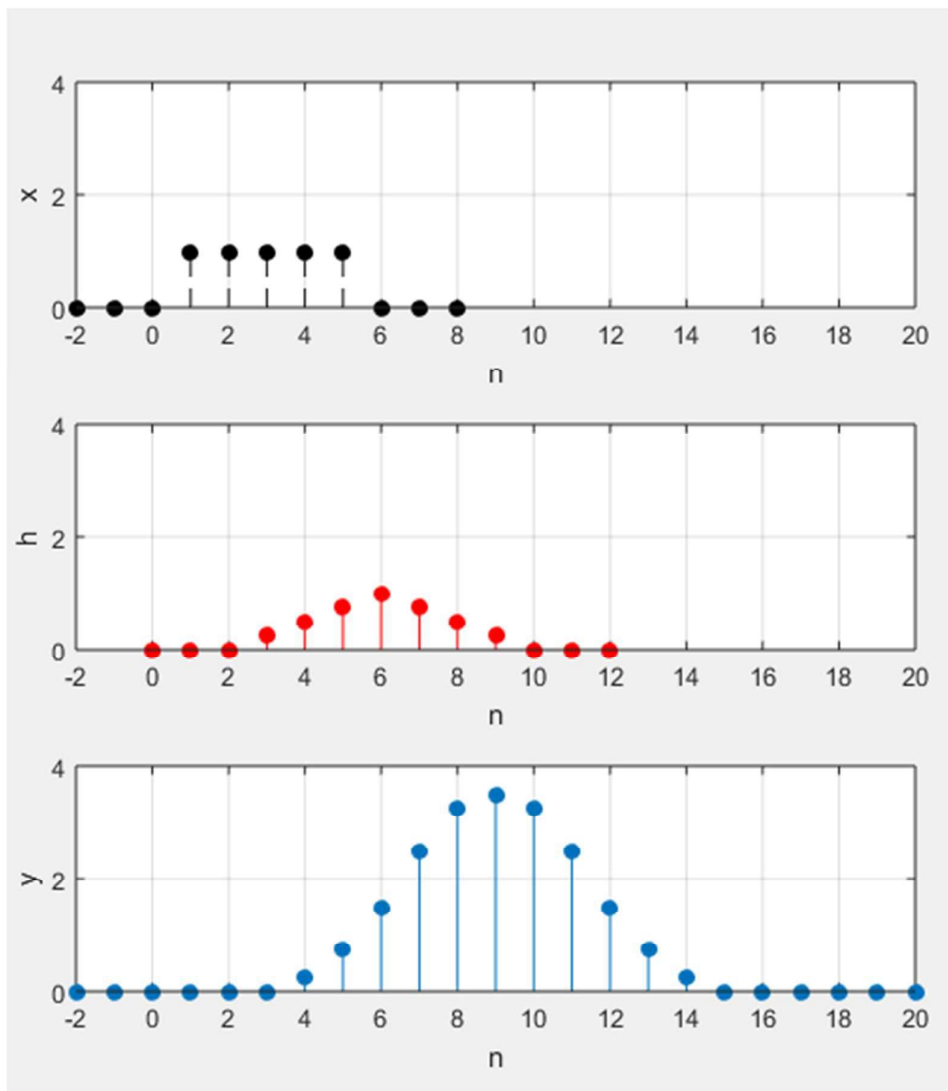
```
Editor - C:\Users\18BIS0043\Documents\MATLAB\r.m
Tl.m x tr.m x u.m x r.m x us.m x +
1      % Function r for triangular function
2      % Needs the function us
3
4      function y = r(x)
5      y = x.*us(x);
```

Final Program: Using 4 functions – 'tr', 'u', 'r', 'us', for different functionalities as shown in the program



```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T1.m
T1.m x tr.m x u.m x r.m x us.m x T2.m x +
1 - clc
2 - clear all
3
4 - nx = -2:8;
5 - nh = 0:12;
6 - x = u(nx-1) - u(nx-6); % Function u is defined
7 - h = tr((nh-6)/4); % Function tr is defined
8 - y = conv(x,h);
9
10 - ny = (nx(1)+nh(1)) + (0:(length(nx)+length(nh)-2));
11
12 - subplot(3,1,1);
13 - stem(nx,x, 'k--', 'filled');
14 - xlabel('n');
15 - ylabel('x');
16 - axis([-2,20,0,4]);
17 - grid on;
18
19 - subplot(3,1,2);
20 - stem(nh,h, 'r', 'filled');
21 - xlabel('n');
22 - ylabel('h');
23 - axis([-2,20,0,4]);
24 - grid on;
25
26 - subplot(3,1,3);
27 - stem(ny,y, 'o', 'filled');
28 - xlabel('n');
29 - ylabel('y');
30 - axis([-2,20,0,4]);
31 - grid on;
32
```

****Output screenshots 1&2 are shown in the next page*



3.2

Program:

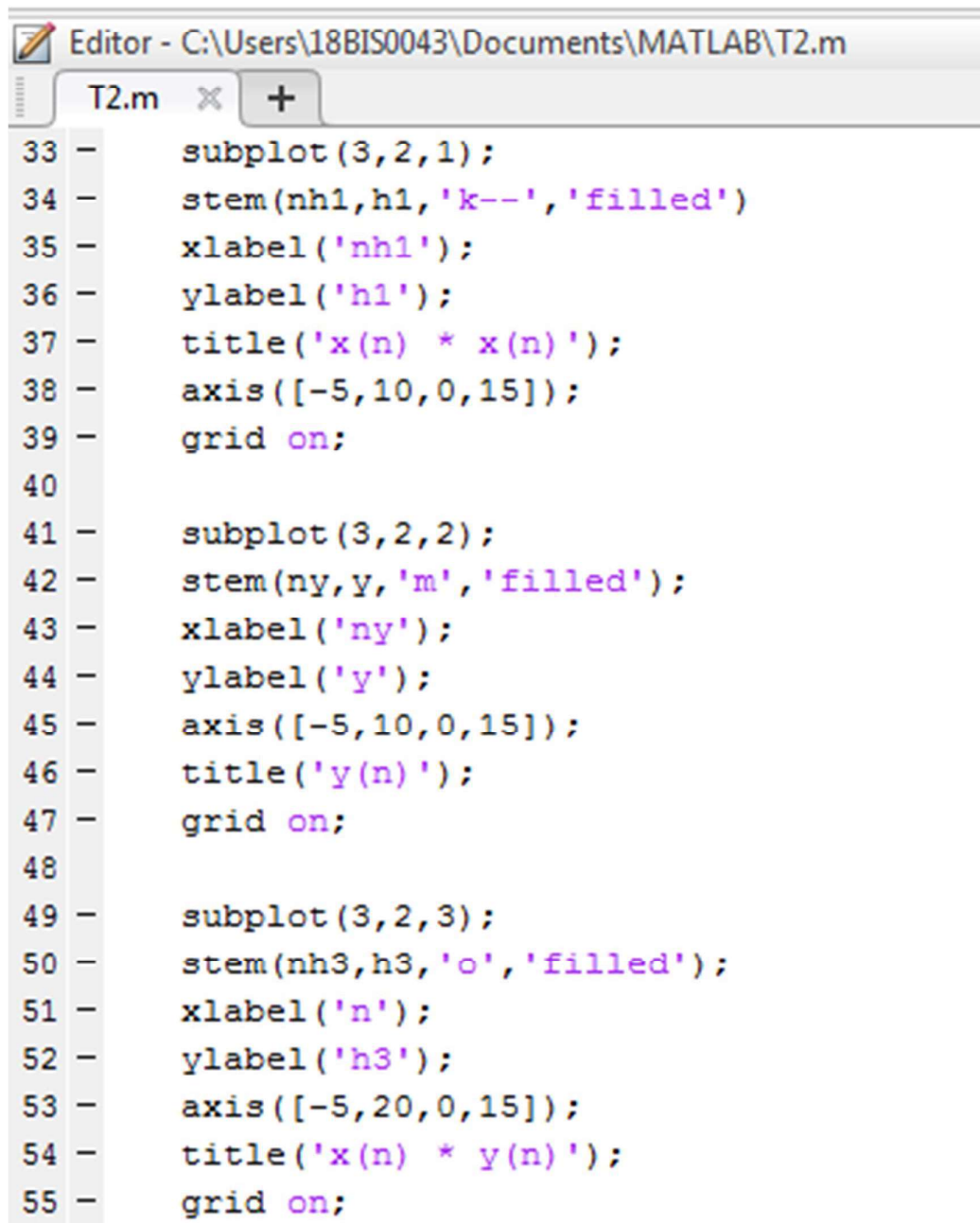
Defining functions 'u', unit impulse function 'd', $x(n)$ and $y(n)$.

```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T2.m
T2.m  x  +
1 -   clc
2 -   clear all
3
4 -   nx = -5:10;
5 -   ny = -5:10;
6 -   nd = -5:10;
7
8 -   d = 1.*(nd==0);
9
10 -  x = u(nx) - u(nx-4); % Function u is defined
11 -  y = ny.*u(ny) - 2.*(ny-4).*u(ny-4) + (ny-8).*u(ny-8);
12
```

*** $h1 - h5$ are signals corresponding to the sub-question (a to e).

```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T2.m
T2.m  x  +
12
13 -  h1 = conv(x,x);
14 -  nh1 = (nx(1)+nx(1)) + (0:(length(nx)+length(nx)-2));
15
16 -  % Convolution is associative
17 -  % x(n)*x(n)*x(n) = (x(n)*x(n))*x(n)
18 -  s = conv(x,x);
19 -  s2 = (nx(1)+ny(1)) + (0:(length(nx)+length(ny)-2));
20 -  h2 = conv(s,x);
21 -  nh2 = (nx(1)+s2(1)) + (0:(length(nx)+length(s2)-2));
22
23
24 -  h3 = conv(x,y);
25 -  nh3 = (nx(1)+ny(1)) + (0:(length(nx)+length(ny)-2));
26
27 -  h4 = conv(y,d);
28 -  nh4 = (nx(1)+nd(1)) + (0:(length(nx)+length(nd)-2));
29
30 -  h5 = conv(y,y);
31 -  nh5 = (ny(1)+ny(1)) + (0:(length(ny)+length(ny)-2));
32
```

Plotting the first 3 graphs:



```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T2.m
T2.m x +
33 - subplot(3,2,1);
34 - stem(nh1,h1,'k--','filled')
35 - xlabel('nh1');
36 - ylabel('h1');
37 - title('x(n) * x(n)');
38 - axis([-5,10,0,15]);
39 - grid on;
40
41 - subplot(3,2,2);
42 - stem(ny,y,'m','filled');
43 - xlabel('ny');
44 - ylabel('y');
45 - axis([-5,10,0,15]);
46 - title('y(n)');
47 - grid on;
48
49 - subplot(3,2,3);
50 - stem(nh3,h3,'o','filled');
51 - xlabel('n');
52 - ylabel('h3');
53 - axis([-5,20,0,15]);
54 - title('x(n) * y(n)');
55 - grid on;
```


Plotting the last 3 graphs:

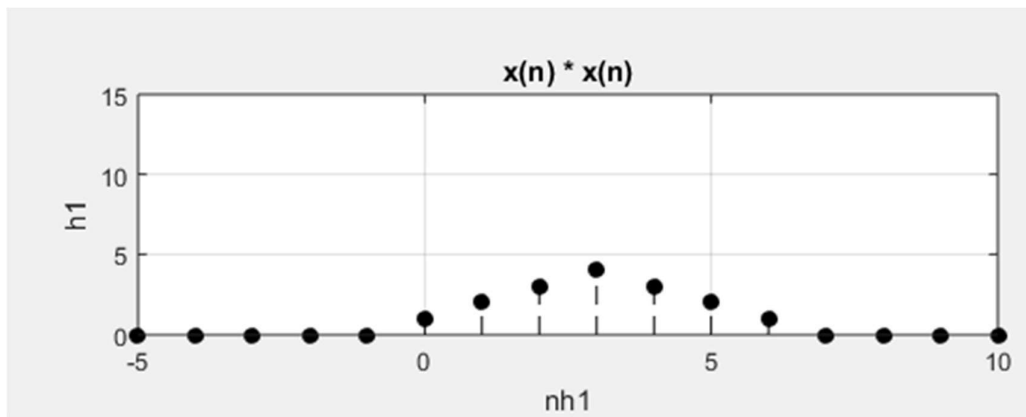


The image shows a MATLAB Editor window titled 'Editor - C:\Users\18BIS0043\Documents\MATLAB\T2.m'. The window contains a script with three subplots. The first subplot (line 57-63) is titled 'y(n) * d(n)' and uses green filled stems. The second subplot (line 65-71) is titled 'y(n) * y(n)' and uses red dashed filled stems. The third subplot (line 73-79) is titled 'x(n) * x(n) * x(n)' and uses blue dashed filled stems. All subplots have an x-axis from -5 to 20 and a y-axis from 0 to 15 or 60. The grid is turned on for each plot.

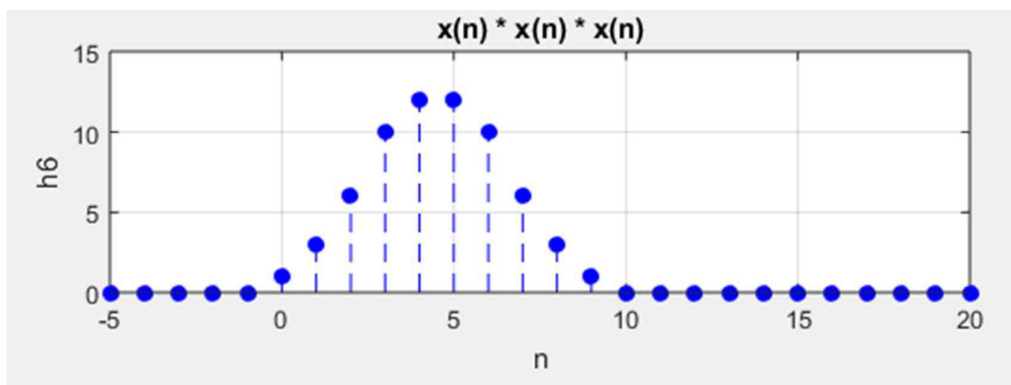
```
56
57 - subplot(3,2,4);
58 - stem(nh4,h4,'g','filled');
59 - xlabel('n');
60 - ylabel('h4');
61 - axis([-5,20,0,15]);
62 - title('y(n) * d(n)');
63 - grid on;
64
65 - subplot(3,2,5);
66 - stem(nh5,h5,'r--','filled');
67 - xlabel('n');
68 - ylabel('h5');
69 - axis([-5,20,0,60]);
70 - title('y(n) * y(n)');
71 - grid on;
72
73 - subplot(3,2,6);
74 - stem(nh2,h2,'b--','filled');
75 - xlabel('n');
76 - ylabel('h6');
77 - axis([-5,20,0,15]);
78 - title('x(n) * x(n) * x(n)');
79 - grid on;
```

Outputs:

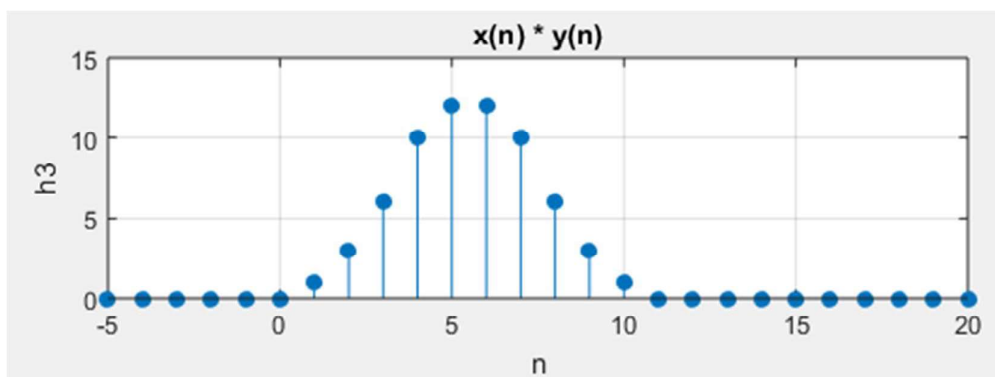
i.



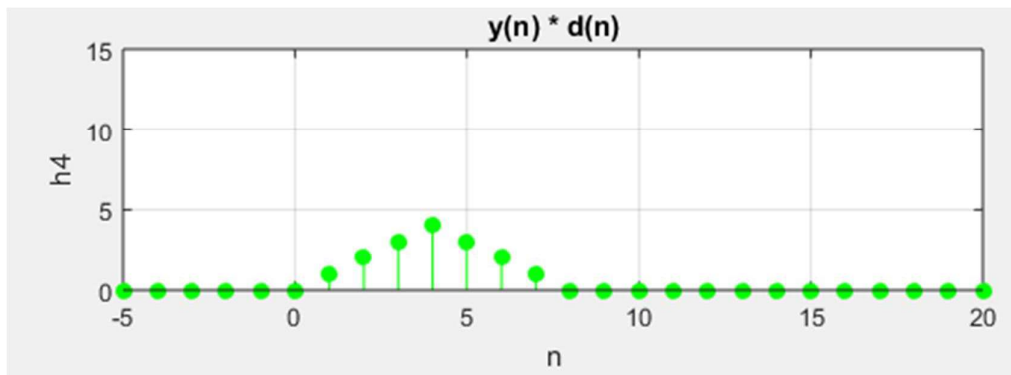
ii.



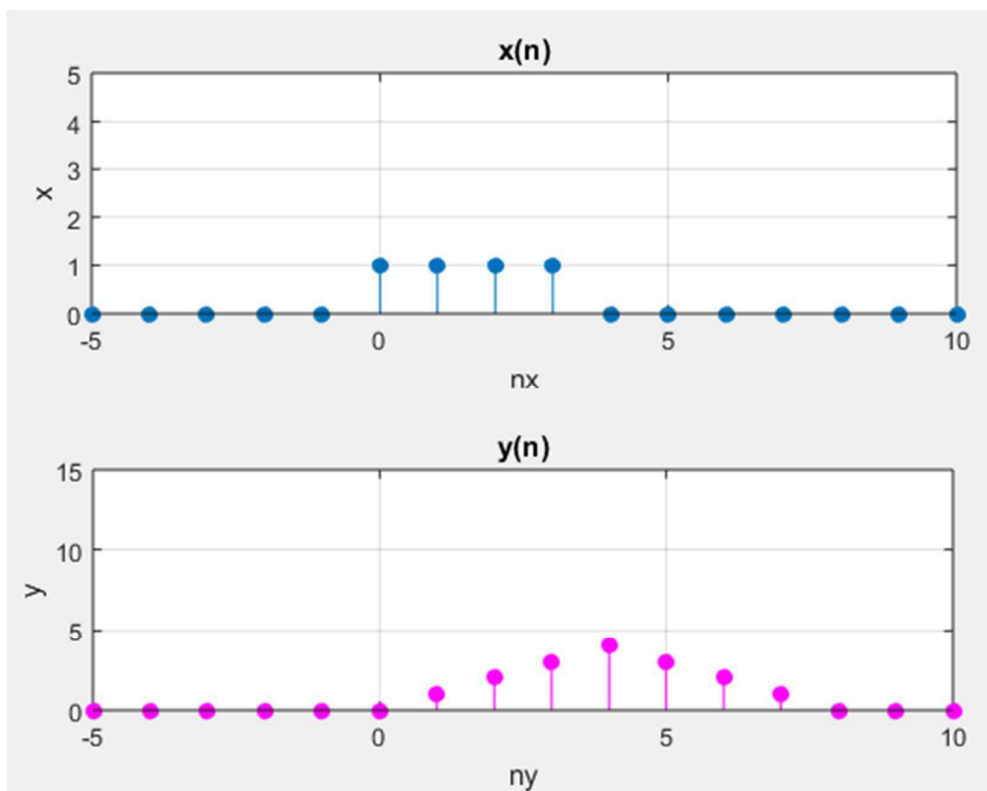
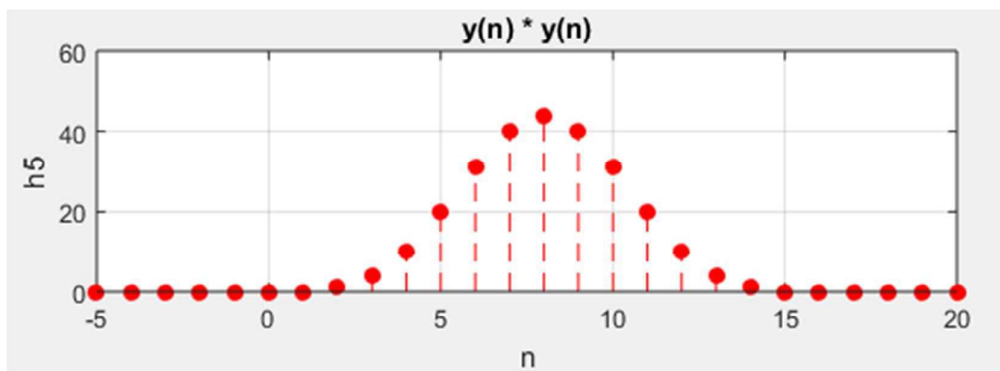
iii.



iv.



v.



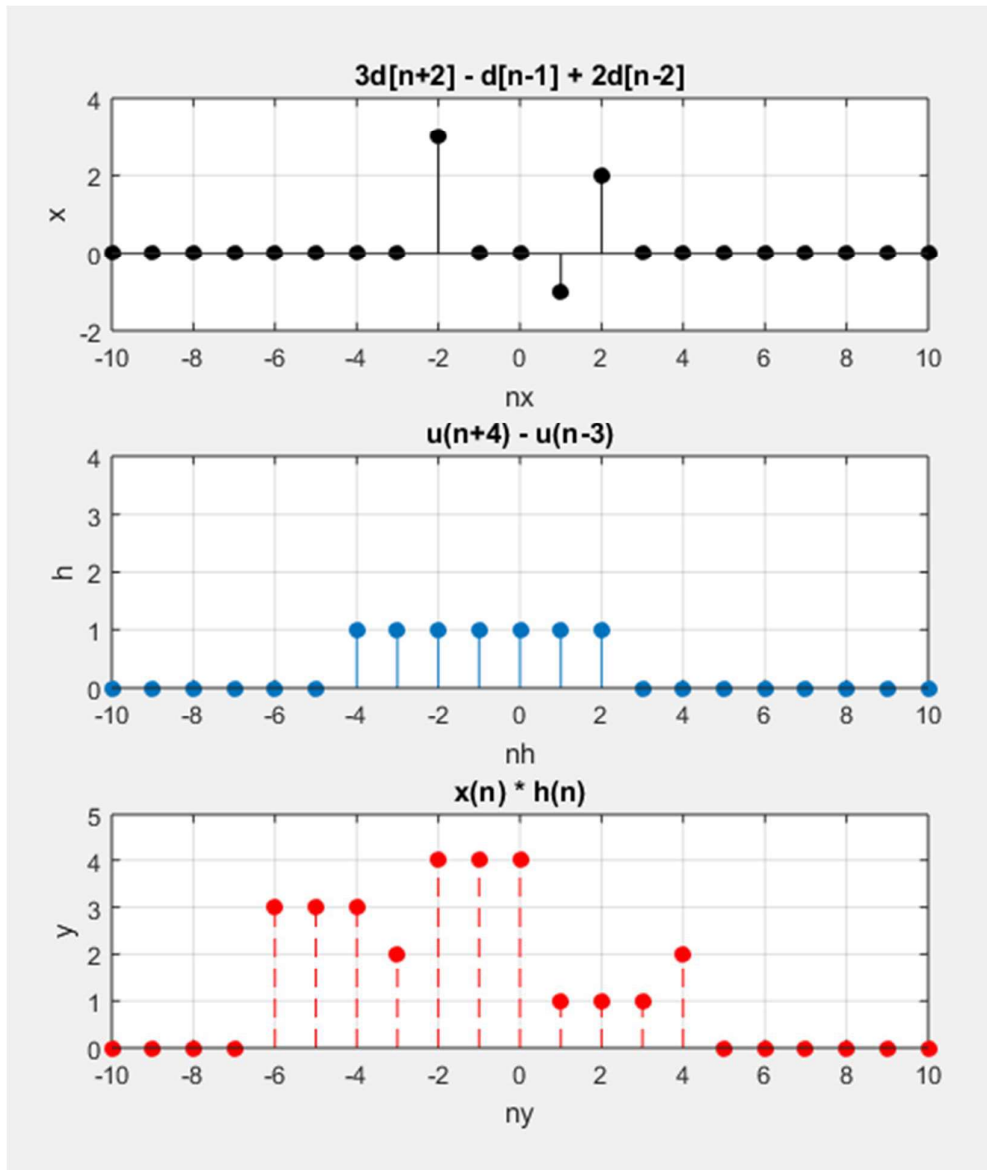
3.3

Program:

```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T3.m
T2.m x u.m x us.m x T3.m x +
1 -   clc
2 -   clear all
3
4 -   nx = -10:10;
5 -   nh = -10:10;
6 -   nd = -10:10;
7 -   d1 = 3.*(nd==2);    % 3d[n+2]
8 -   d2 = 1.*(nd==1);    % d[n-1]
9 -   d3 = 2.*(nd==2);    % 2d[n-2]
10
11 -   h = u(nh+4) - u(nh-3); % Function u is defined
12 -   x = d1-d2+d3;
13
14 -   y = conv(x,h);
15 -   ny = (nx(1)+nh(1)) + (0:(length(nx)+length(nh)-2));
16
```

```
Editor - C:\Users\18BIS0043\Documents\MATLAB\T3.m
T2.m x u.m x us.m x T3.m x +
18 -   stem(nx,x,'k','filled')
19 -   xlabel('nx');
20 -   ylabel('x');
21 -   title('3d[n+2] - d[n-1] + 2d[n-2]');
22 -   axis([-10,10,-2,4]);
23 -   grid on;
24
25 -   subplot(3,1,2)
26 -   stem(nh,h,'o','filled')
27 -   xlabel('nh');
28 -   ylabel('h');
29 -   title('u(n+4) - u(n-3)');
30 -   axis([-10,10,0,4]);
31 -   grid on;
32
33 -   subplot(3,1,3)
34 -   stem(ny,y,'r--','filled')
35 -   xlabel('ny');
36 -   ylabel('y');
37 -   title('x(n) * h(n)');
38 -   axis([-10,10,0,5]);
39 -   grid on;
40
```

Output:



***Unit Step function 'u' (from page 1) is also used in this program.

Experiment - 3: Answers

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3.2 vi) $x[n] * x[n]$ and $y[n]$ are similar graphs with time shifting by 1 unit

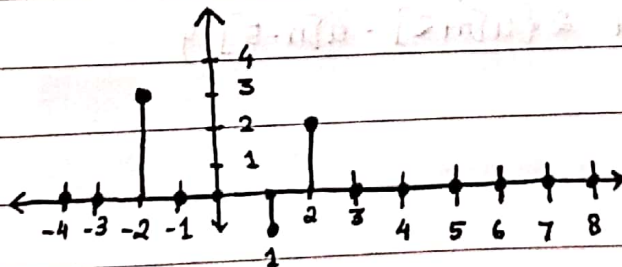
$$\therefore \text{if } a[n] = x[n] * x[n]$$

$$\Rightarrow a[n] = y[n+1]$$

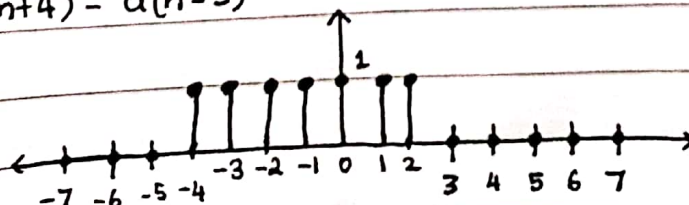
After the first convolution, there will be a triangular distribution, whose base will become broader and peak becomes smoother and asymptotically gaussian. Broader base represents a wider range.

increasing each convolution

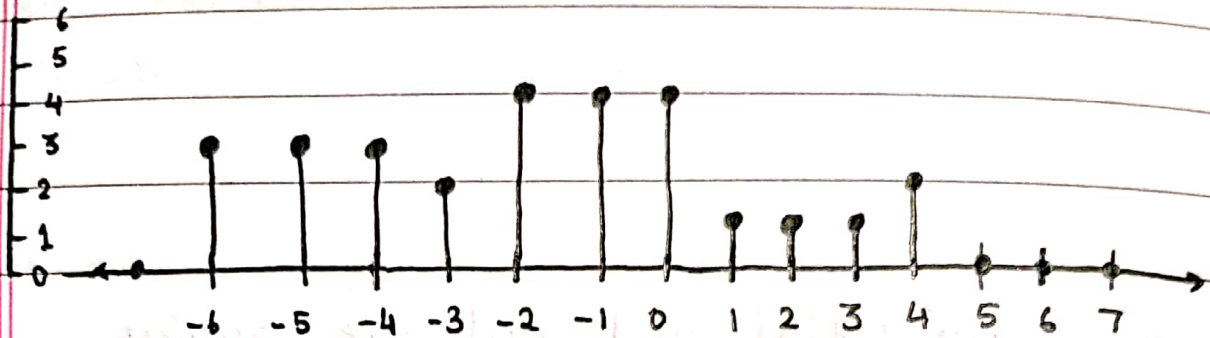
3.3 ii] a. $3\delta[n+2] - \delta[n-1] + 2\delta[n-2]$



ii] b. $u[n+4] - u[n-3]$



ii) c. $x[n] * h[n]$



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$$z[n] = \sum_{-\infty}^{\infty} x[k] h[n-k]$$

$$= \sum_{-n}^n x[k] h[n-k]$$

$$= 3h[n+2] - h[n-1] + 2h[n-2]$$

$$= 3\{u[n+6] - u[n-1]\}$$

$$- u[n+3] - u[n-k]$$

$$+ 2\{u[n+2] - u[n-5]\}$$