ELECENG 3TP3 – Signals and Systems

Lab 2: Signal Convolution

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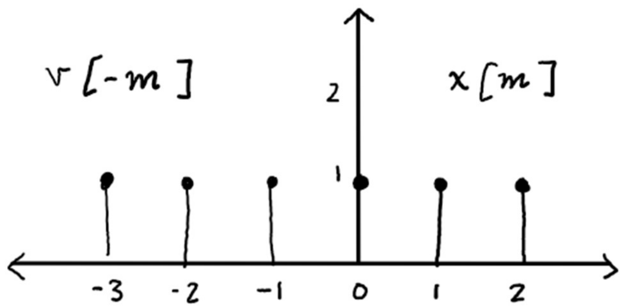
Table of Contents

Part 1 – Textbook Question 2.7

1) Manual Convolution

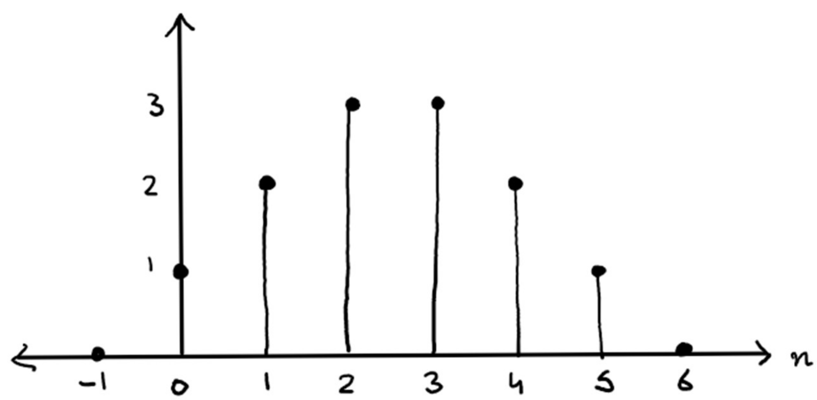
2.7 a) $x[n] * v[n] = \sum_{m=-\infty}^{\infty} x[m]\, v[n-m]$



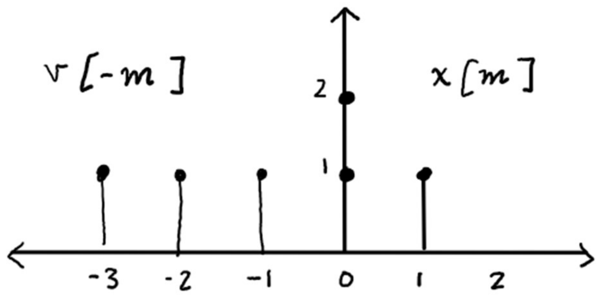
- no overlap for $n < 0$
- no overlap for $n \geq 6$

n	0	1	2	3	4	5	6
$x[n] * v[n]$	1	2	3	3	2	1	0

final answer



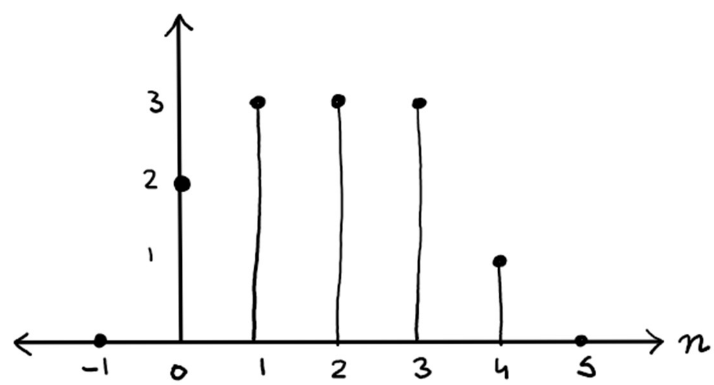
2.7 b) $x[n] * v[n] = \sum_{m=-\infty}^{\infty} x[m]\, v[n-m]$



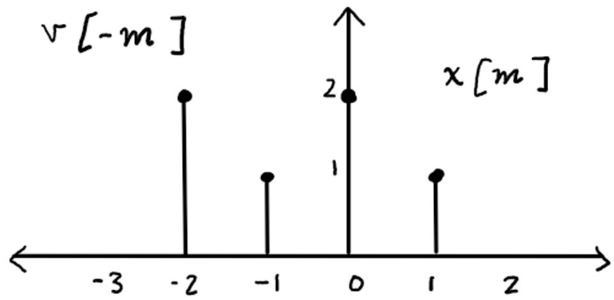
- no overlap for $n < 0$
- no overlap for $n \geq 5$

n	0	1	2	3	4	5
$x[n] * v[n]$	2	3	3	3	1	0

$\boxed{\text{final answer}}$



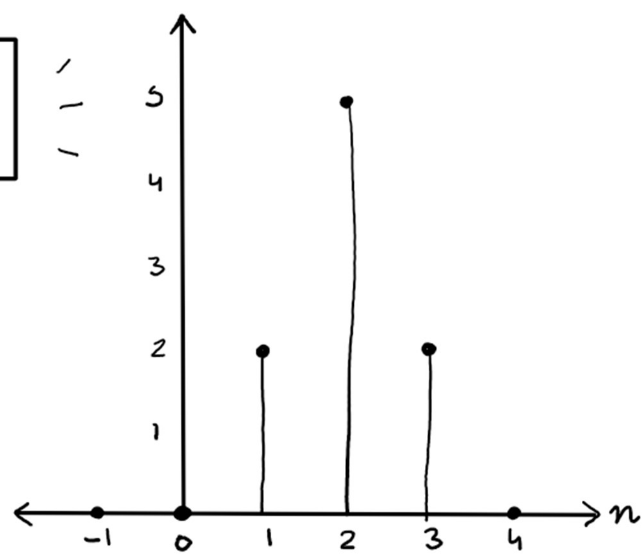
2.7 c) $x[n] * v[n] = \sum_{m=-\infty}^{\infty} x[m]\,v[n-m]$



- no overlap for $n < 1$
- no overlap for $n \geq 4$

n	1	2	3	4
$x[n] * v[n]$	2	5	2	0

$\boxed{\text{final answer}}$

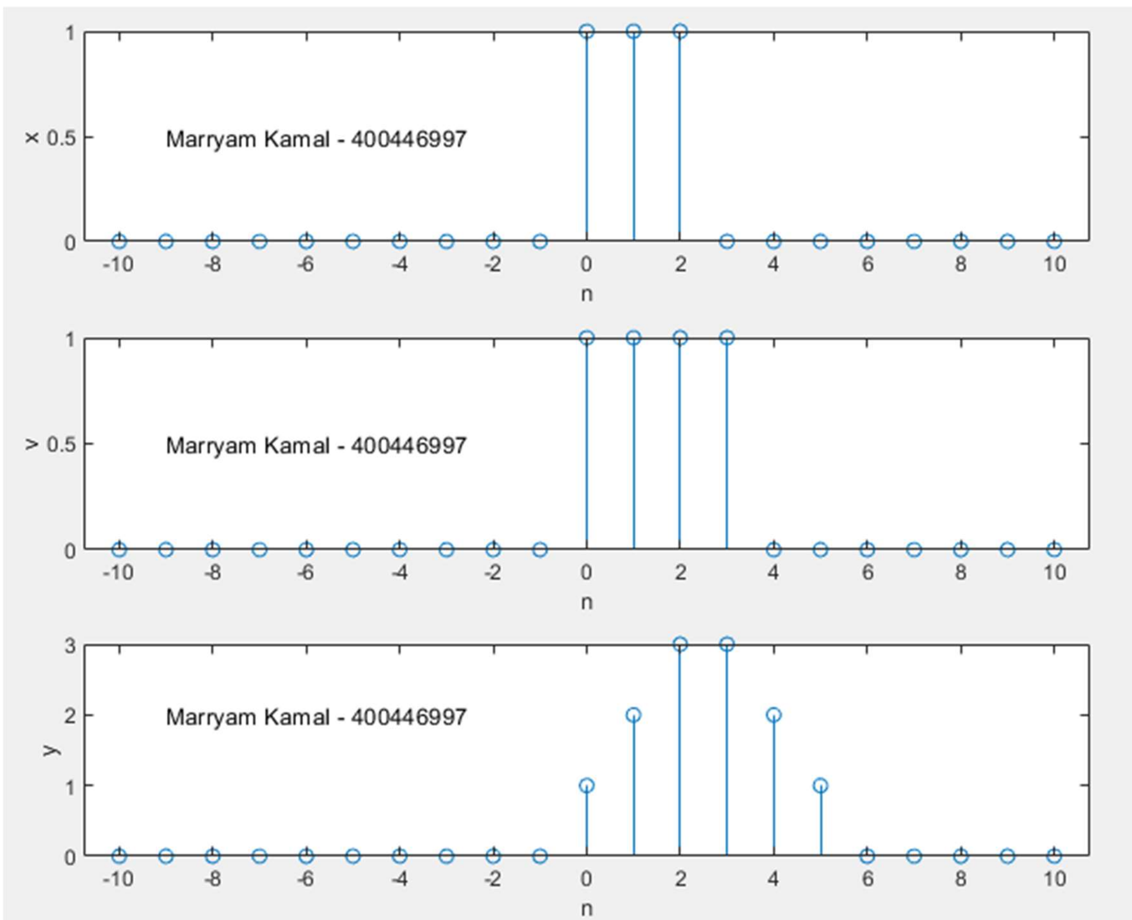


2) Convolution via MATLAB

a) Code:

```
% Question 2.7A
n = -10:1:10;
x = f.unitstep(n) - f.unitstep(n-3);
v = f.unitstep(n) - f.unitstep(n-4);
y = conv(x, v, "same");
subplot(3,1,1); stem(n,x);
xlabel('n'); ylabel('x');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,2); stem(n,v);
xlabel('n'); ylabel('v');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,3); stem(n,y);
xlabel('n'); ylabel('y');
text(-9, 2,'Marryam Kamal - 400446997', 'FontSize', 10)
```

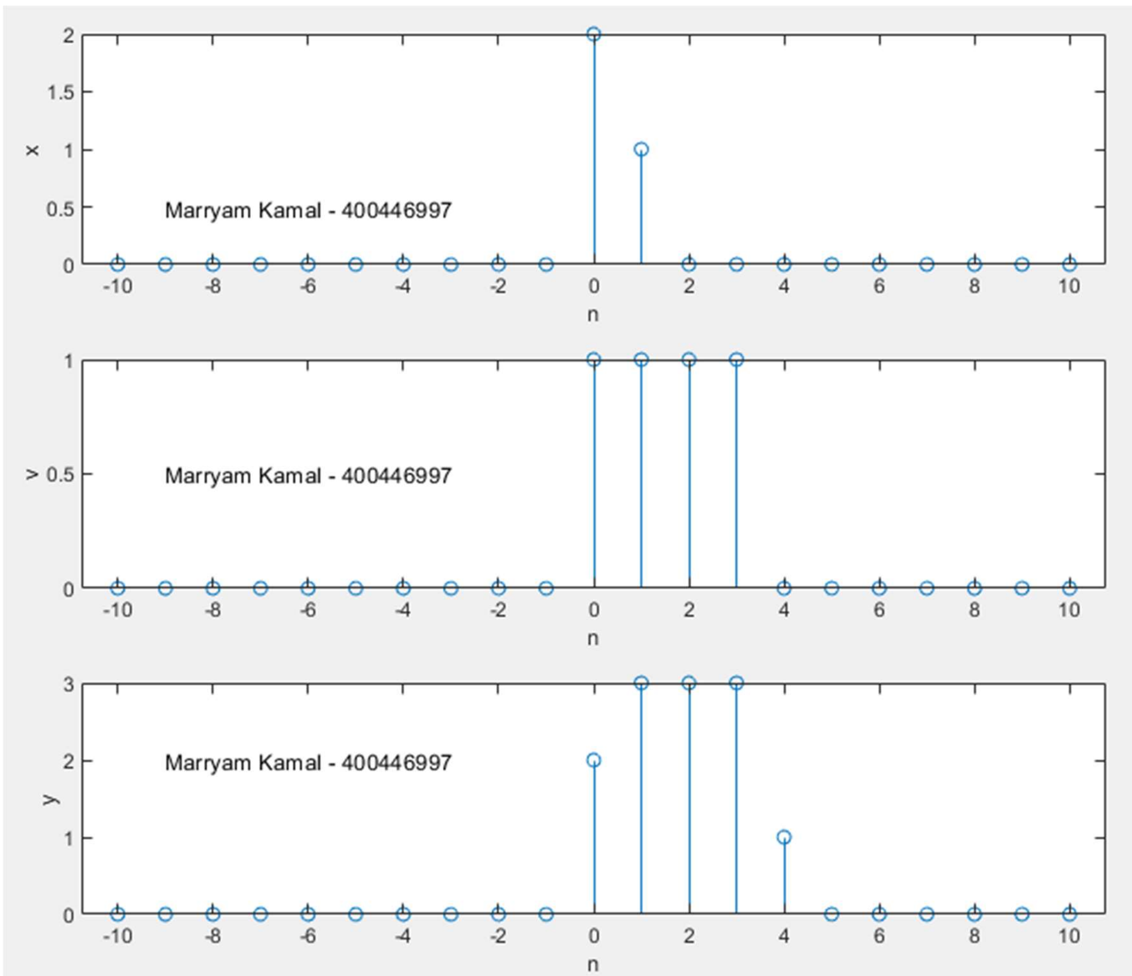
Plot:



b) Code:

```
% Question 2.7B
n = -10:1:10;
x = 2*f.delta(n) + f.delta(n-1);
v = f.unitstep(n) - f.unitstep(n-4);
y = conv(x, v, "same");
subplot(3,1,1); stem(n,x);
xlabel('n'); ylabel('x');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,2); stem(n,v);
xlabel('n'); ylabel('v');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,3); stem(n,y);
xlabel('n'); ylabel('y');
text(-9, 2,'Marryam Kamal - 400446997', 'FontSize', 10)
```

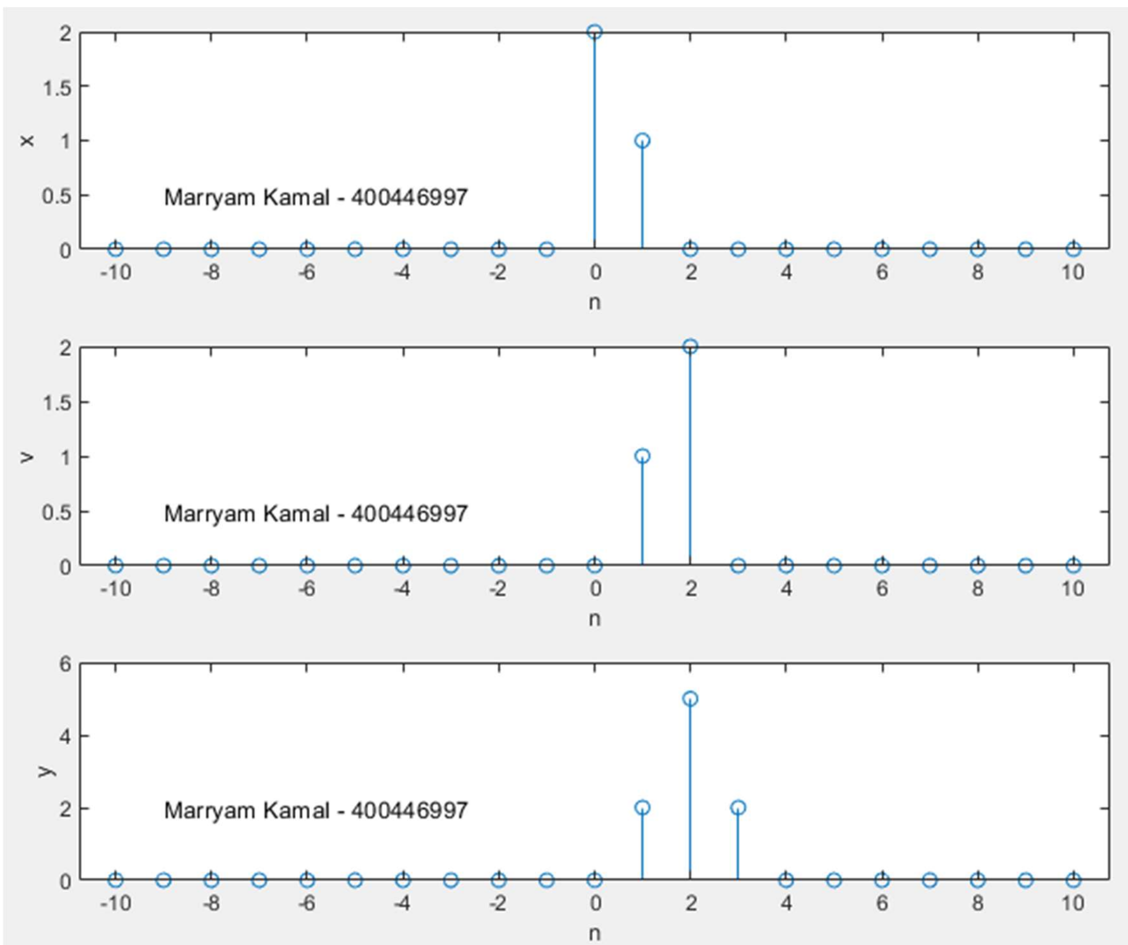
Plot:



c) Code:

```
% Question 2.7C
n = -10:1:10;
x = 2*f.delta(n) + f.delta(n-1);
v = f.delta(n-1) + 2*f.delta(n-2);
y = conv(x, v, "same");
subplot(3,1,1); stem(n,x);
xlabel('n'); ylabel('x');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,2); stem(n,v);
xlabel('n'); ylabel('v');
text(-9, 0.5,'Marryam Kamal - 400446997', 'FontSize', 10)
subplot(3,1,3); stem(n,y);
xlabel('n'); ylabel('y');
text(-9, 2,'Marryam Kamal - 400446997', 'FontSize', 10)
```

Plot:



Part 2 – Audio Processing

3) Code:

```
% Audio importing
[signal, Fs] = audioread('my_speech_clip.wav');
L = length(signal);
T = 1/Fs;
t = [0:L-1]*T;
```

4) Code:

```
a = 0.5;                              % Echo amplitude
Te = 200;                             % Echo delay in msec
Te_samples = round((Te/1000) * Fs);   % Convert echo delay to samples


signal(Te_samples+1:end) = signal(Te_samples+1:end) + a*signal(1:end-Te_samples);
signal = signal / max(abs(signal));

% New audio file
audiowrite('speechwithecho.wav', signal, Fs);
```

5) Choice of Impulse Response:

An echo has 2 components: the original sound and a scaled, delayed version. To achieve this, the impulse response I must convolve the original signal with must overlap in those two locations. This means it must have a delta function at t = 0, and then one at t = Te, the delay. Doing so creates the following formula.

$$IR = \delta(t) + a\delta(t - Te)$$

And so, I created a delta function IR which has a value of $\delta(t) = 1$ at $t = 0$ and $\delta(t) = a$ at $t = Te$.

Code:

```
a = 0.5;                              % Echo amplitude
Te = 200;                             % Echo delay in msec
Te_samples = round((Te/1000) * Fs);   % Convert echo delay to samples

IR = zeros(1, Te_samples + 1);
IR(1) = 1;                     % Delta function at t = 0
IR(Te_samples + 1) = a;

signal = conv(signal, IR, 'full');  % Convolution
signal = signal / max(abs(signal));

% New audio file
audiowrite('echo_convolution.wav', signal, Fs);
```

6) Changing Te and a:

Keeping a = 1, I found that the signal sounded the best on values of Te < 10 ms. The shorter the time between the original speech and echo, the better it will sound. When I decreased a to 0.1, I found that the signal sounded best on values of Te < 100 ms. From this, I can tell that lowering the amplitude, or volume of the audio can further reduce the echo in it.

7) Reverberation:

To achieve reverberation, I first created a vector function impulse response (IR) and then added Ne delta functions to it, each with a decreasing amplitude up to Te. Convolving this with the original resulted in the reservation I needed.

Code:

```
a = 0.5;                              % Echo amplitude
Te = 200;                             % Echo delay in msec
Te_samples = round((Te/1000) * Fs);   % Convert echo delay to samples
Ne = 5;

IR = zeros(1, Ne*Te_samples + 1);     % Create IR vector
for i = 0:Ne-1
    IR(round(i*Te_samples) + 1) = a^i;
end

signal = conv(signal, IR, 'same'); % Convolve
signal = signal / max(abs(signal));

% New audio file
audiowrite('speechwithreverb.wav', signal, Fs);
```