Ryerson University

Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Title:	Signals and Systems II
Course Number:	W2023
Semester/Year (e.g.F2016)	W2023

Instructor:	Dr. Androutsos

Assignment/Lab Number:	Lab 2
Assignment/Lab Title:	Time-Domain Analysis of Discrete-Time Systems-Part 2

Submission Date:	2023-02-12
Due Date:	2023-02-19

Student LAST Name	Student FIRST Name	Student Number	Section	Signature*
Zelenovic	Danilo	501032542	08	DZ

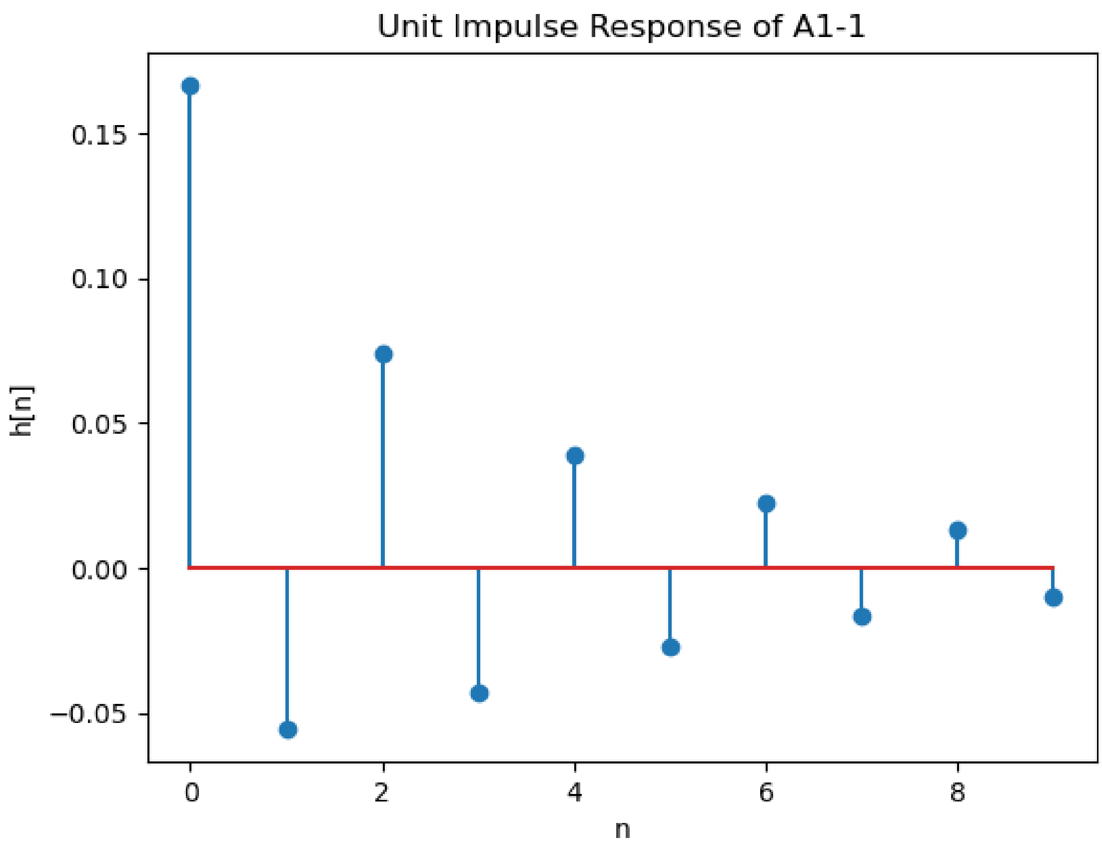
*By signing above you attest that you have contributed to this written lab report and confirm that all work you have contributed to this lab report is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a “0” on the work, an “F” in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: http://www.ryerson.ca/senate/current/pol60.pdf

ELE632_Lab2_DaniloZelenovic_501032542_Section08

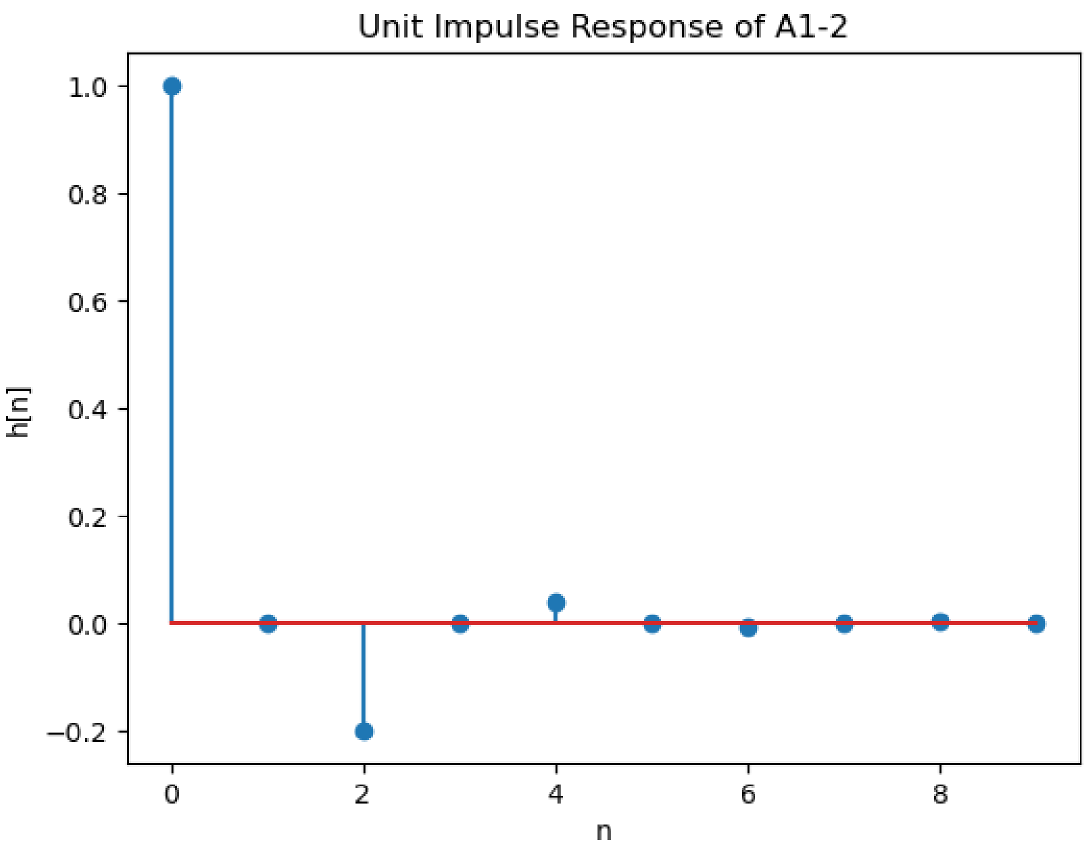
February 13, 2023

[ ]:
```
#NOTE: STUDENT ID AND CORRESPONDING STUDENT ID LETTERS WOULD BE

# 5 0 1 0 3 2 5 4 2
# A B C D E F G H I
```

[20]:
```
#A1-1

import numpy as np
import matplotlib.pyplot as plt
from scipy import signal

n = np.arange(0,10)
delta = lambda n:(1.0*(n==0))
E = np.array([1/6, 0, 0])
Q = np.array([1, 1/3, -1/3])

#signal.lfiltic(Q, E, delta(n))
h = signal.lfilter(E, Q, delta(n))


plt.stem(n,h)
plt.title('Unit Impulse Response of A1-1')
plt.xlabel('n')
plt.ylabel('h[n]')
plt.show()
```



[74]:
```
#A1-2

import numpy as np
import matplotlib.pyplot as plt
from scipy import signal

n = np.arange(0,10)
delta = lambda n:(1.0*(n==0))
E = np.array([1, 0, 0])
Q = np.array([1, 0, 1/5])

#signal.lfiltic(Q, E, delta(n))
h = signal.lfilter(E, Q, delta(n))

plt.stem(n,h)
plt.title('Unit Impulse Response of A1-2')
plt.xlabel('n')
plt.ylabel('h[n]')
plt.show()
```

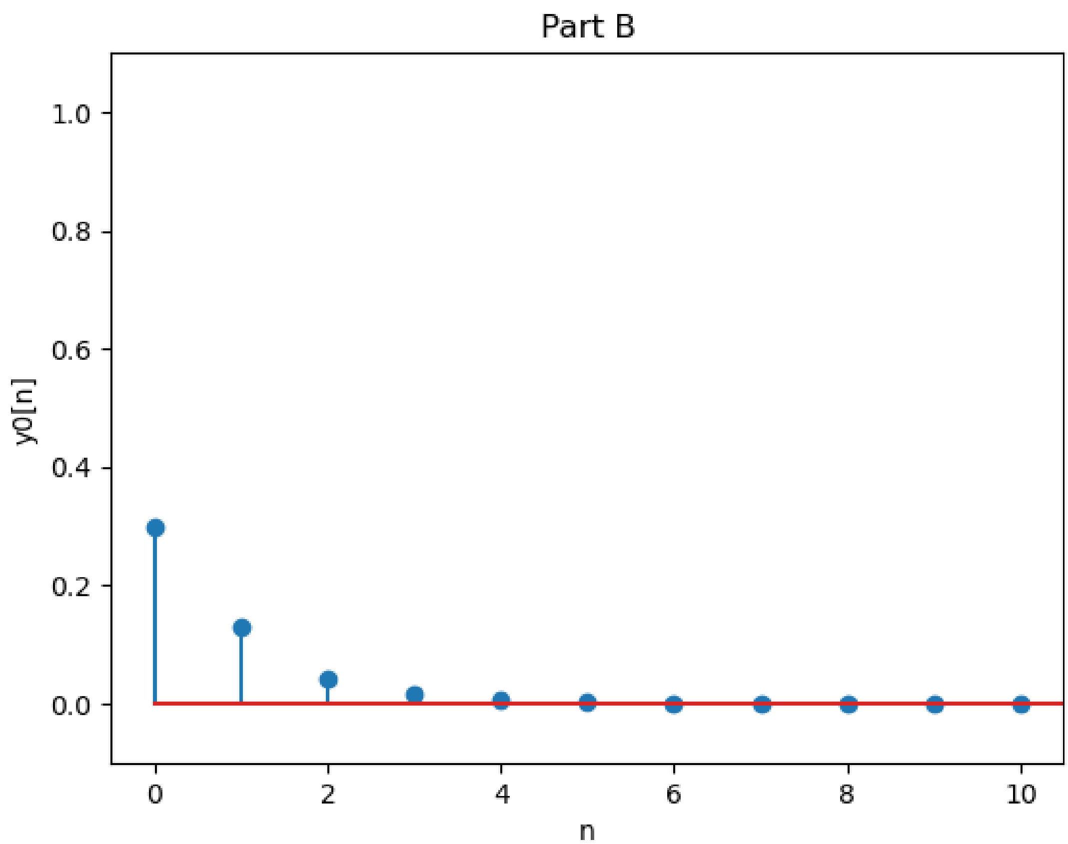



```
[ ]: #A2 and A3 were done on paper, by hand, and will be attached separately in the
     ↪submission as .png files
```

```
[ ]: #Small note: My 'D' value from my student number is 0, so the graph is for a
     ↪very small amount. Change the values of the associated unit spet functions,
     ↪to see a longer version of the graph.
```

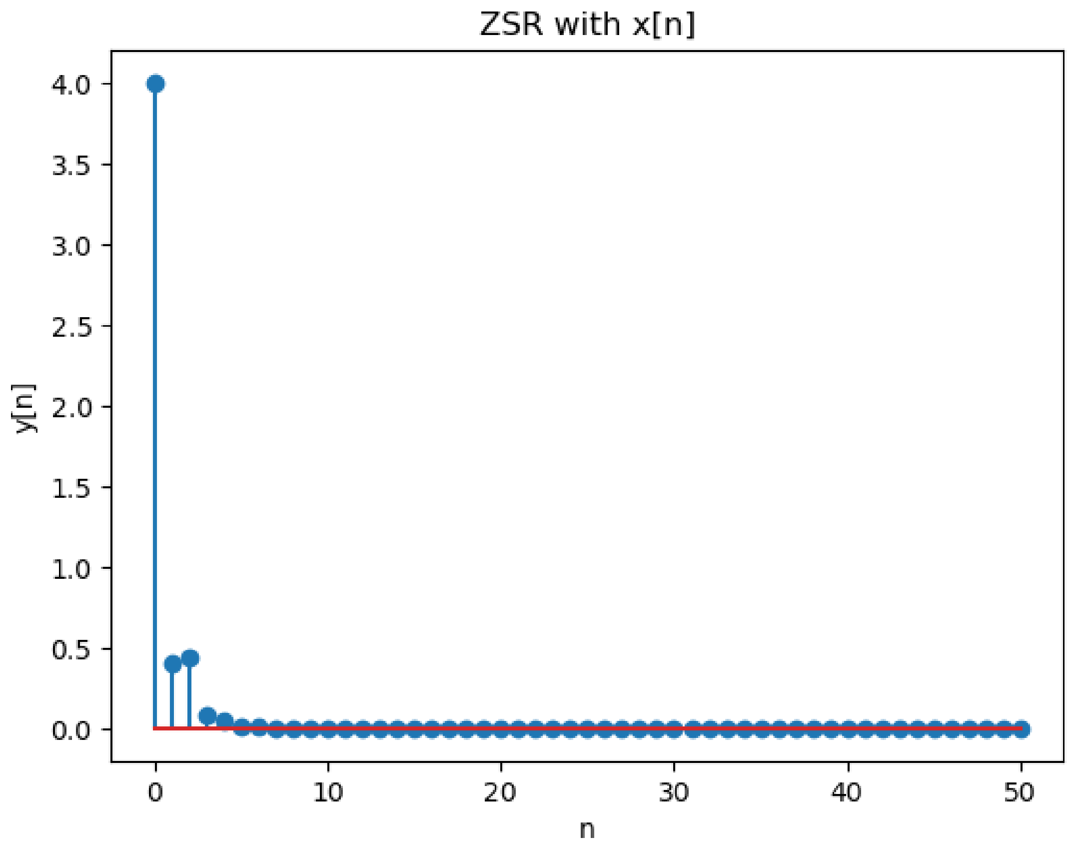
```
[34]: #Part B

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter, lfiltic

b = [2, 0, 0]
a = [1, -1/10, -1/10]

z_i = lfiltic(b, a, [1, 2])
n = np.arange(0, 51)
x = np.zeros(n.shape)
y_0, _ = lfilter(b, a, x, zi=z_i)
```

```
plt.stem(n, y_0)
plt.title('Part B')
plt.axis([-0.5, 10.5, -0.1, 1.1])
plt.xlabel('n')
plt.ylabel('y0[n]')
plt.show()
```



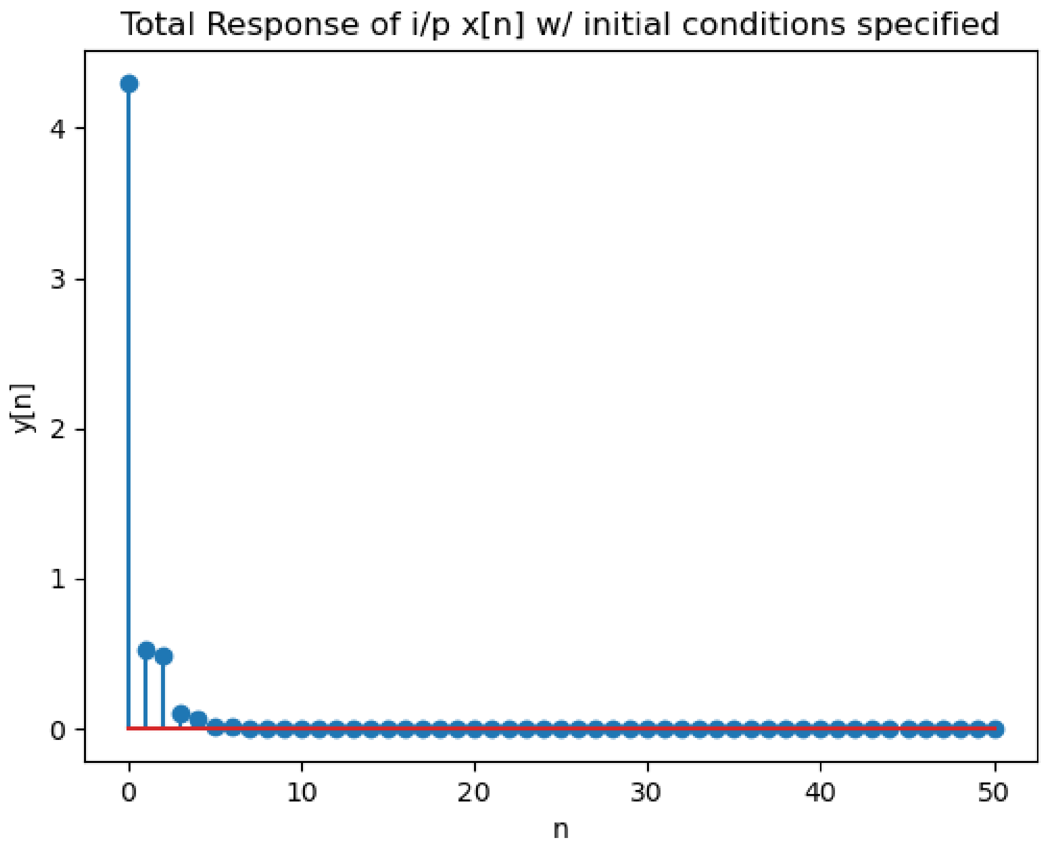
[38]:
```
#Part C

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter, lfiltic, square

E = [2, 0, 0]
Q = [1, -1/10, -1/10]

n = np.arange(0, 51)
x = 2 * np.cos(2 * np.pi * n) * (np.heaviside(n, 1) - np.heaviside(n - 1, 1))
y = lfilter(E, Q, x)
```

```
plt.stem(n, y)
plt.title('ZSR with x[n]')
plt.xlabel('n')
plt.ylabel('y[n]')
plt.show()
```



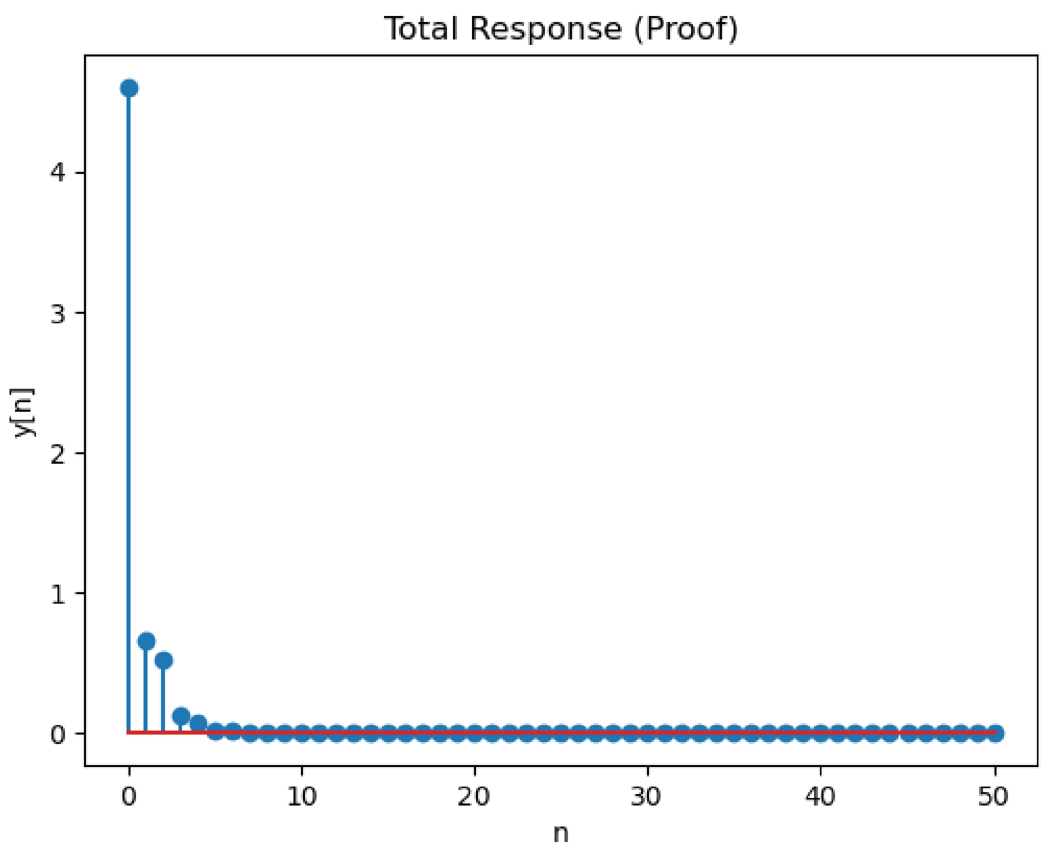
[41]:
```
#PART D-1

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter, lfiltic, square

b = [2, 0, 0]
a = [1, -1/10, -1/10]

n = np.arange(0, 51)
x = 2 * np.cos(2 * np.pi * n) * (np.heaviside(n, 1) - np.heaviside(n - 1, 1))
z_i = lfiltic(b, a, [1, 2])
y, _ = lfilter(b, a, x, zi=z_i)
```

```
plt.stem(n, y)
plt.title('Total Response of i/p x[n] w/ initial conditions specified')
plt.xlabel('n')
plt.ylabel('y[n]')
plt.show()
```



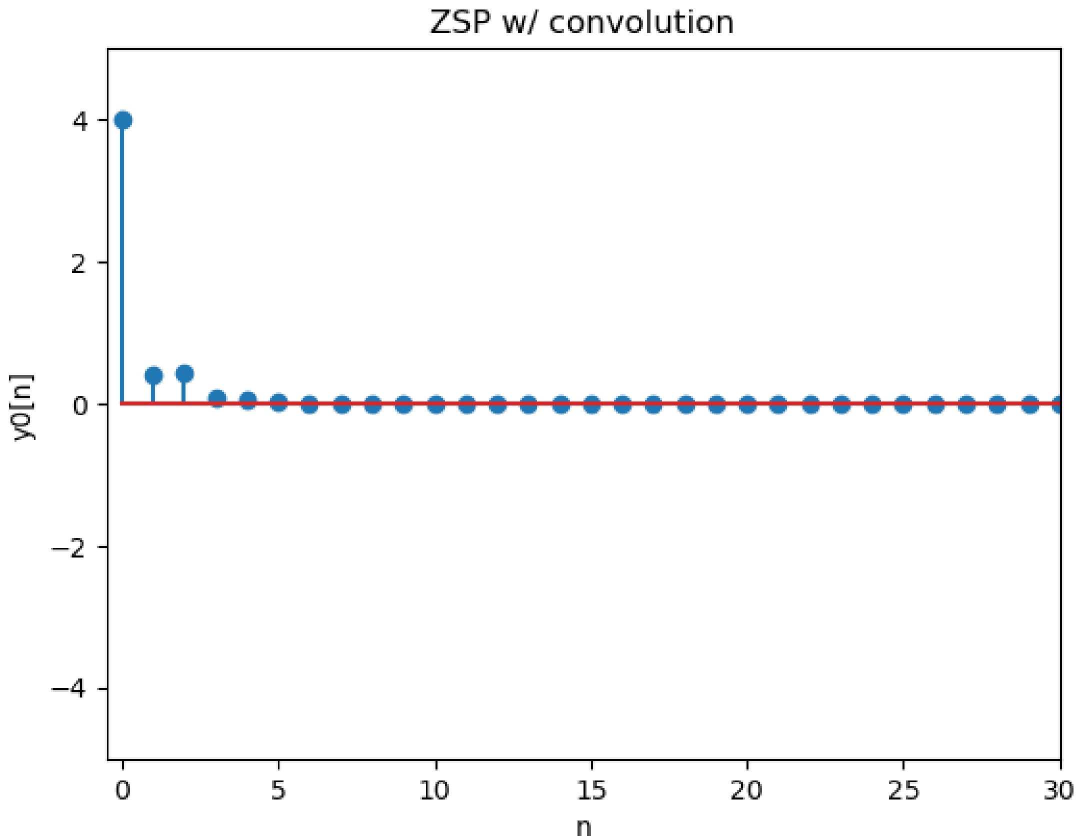
[42]:
```
#D-2

#Yes this is feasible. From just looking, it appears this has been done to come␣
↪up with the Total Response.
#Here, we have double checked this by doing both calculations, adding and␣
↪plotting them on the same graph
#To check and make sure that both graphs would be identical, and they are.

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter, lfiltic, square
```

```
b = [2, 0, 0]
a = [1, -1/10, -1/10]

n = np.arange(0, 51)
x = 2 * np.cos(2 * np.pi * n) * (np.heaviside(n, 1) - np.heaviside(n - 1, 1))

z_i = lfiltic(b, a, [1, 2])
y1, _ = lfilter(b, a, x, zi=z_i)

z_i = lfiltic(b, a, [1, 2])
y0 = lfilter(b, a, np.zeros_like(n), zi=z_i)[0]

y = y0 + y1

plt.stem(n, y)
plt.title('Total Response (Proof)')
plt.xlabel('n')
plt.ylabel('y[n]')
plt.show()
```



[71]:

```
#Part E-1

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import lfilter, convolve

n = np.arange(0, 51)
u = np.where(np.mod(n,1)==0, 1.0, 0.0) * np.where(n>=0, 1.0, 0.0)
u2 = np.where(np.mod(n,1)==0, 1.0, 0.0) * np.where(n>=1, 1.0, 0.0)
b = np.array([2, 0, 0])
a = np.array([1, -1/10, -1/10])
x = 2. * np.cos((2. * np.pi * n) / 1) * (u - u2)

delta = np.where(n==0, 1, 0)

h = lfilter(b, a, delta)

y = convolve(x, h)

n = np.arange(0, 101)

plt.stem(n, y)
plt.title('ZSP w/ convolution')
plt.axis([-0.5, 30, -5, 5])
plt.xlabel('n')
plt.ylabel('y0[n]')
plt.show()
```



[5]:
```
#Part E-2

# The results appear to be identical in the graphs.

#Part E-3

# Yes, the system is asymptotically stable, as two real roots exist withing the
  ↪Unit Circle.
```

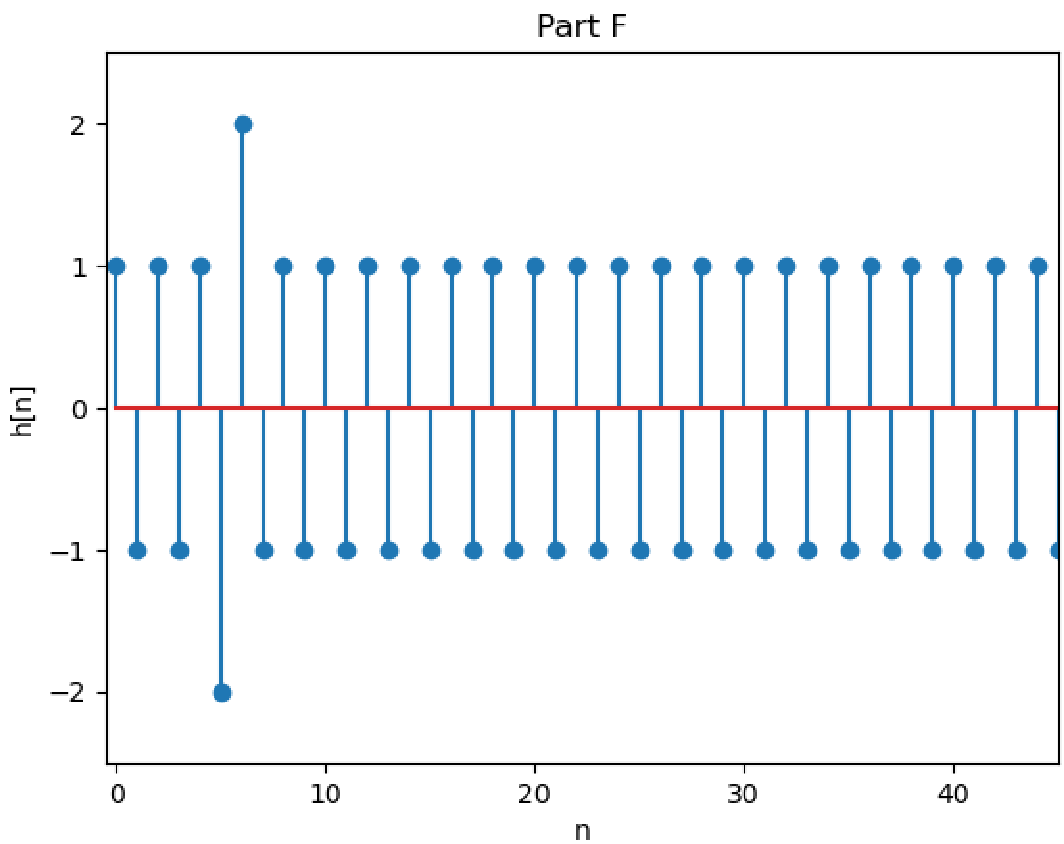
[73]:
```
#Part F-1

#We can see by convolving h[k] with x[n-k] from 0 to infinity and so we can say
#the constant coefficient difference equation for the N-point moving average
  ↪filter is:
#y[n] = (1/N) (x[n] + x[n - 1] + ... + x[n - (N - 1)])
```

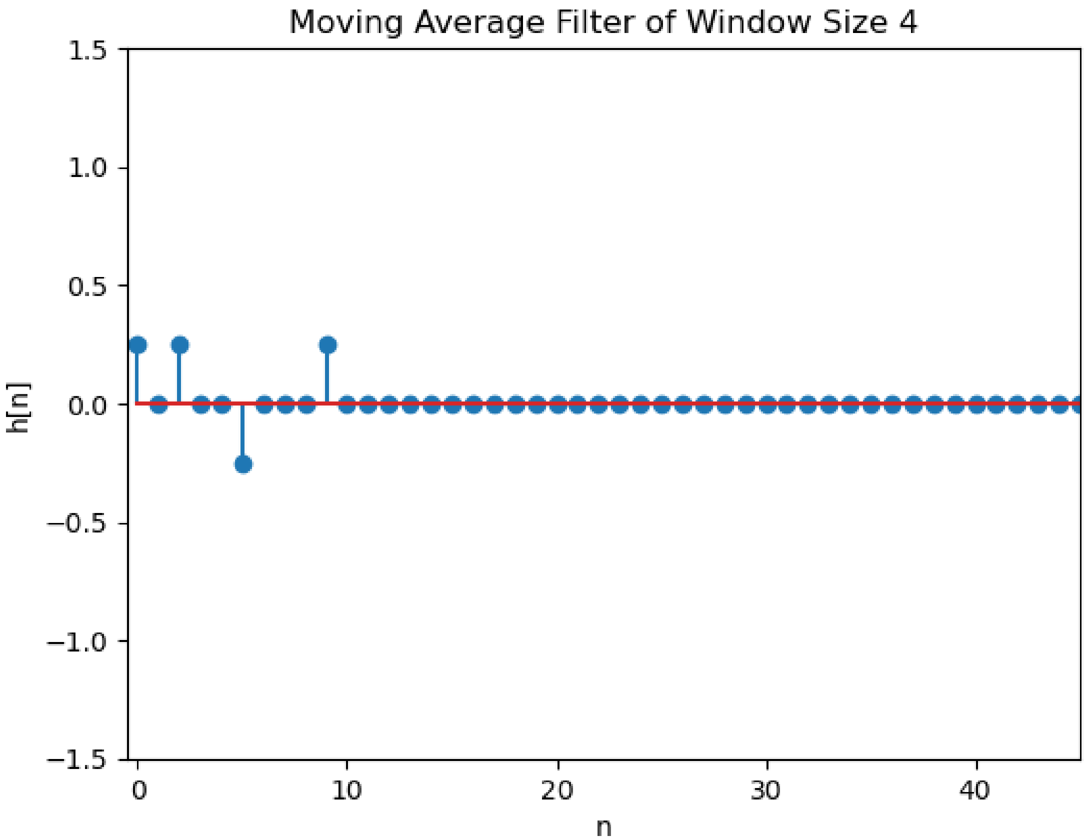
[1]:
```
#Part F-2/3

import numpy as np
import matplotlib.pyplot as plt
```

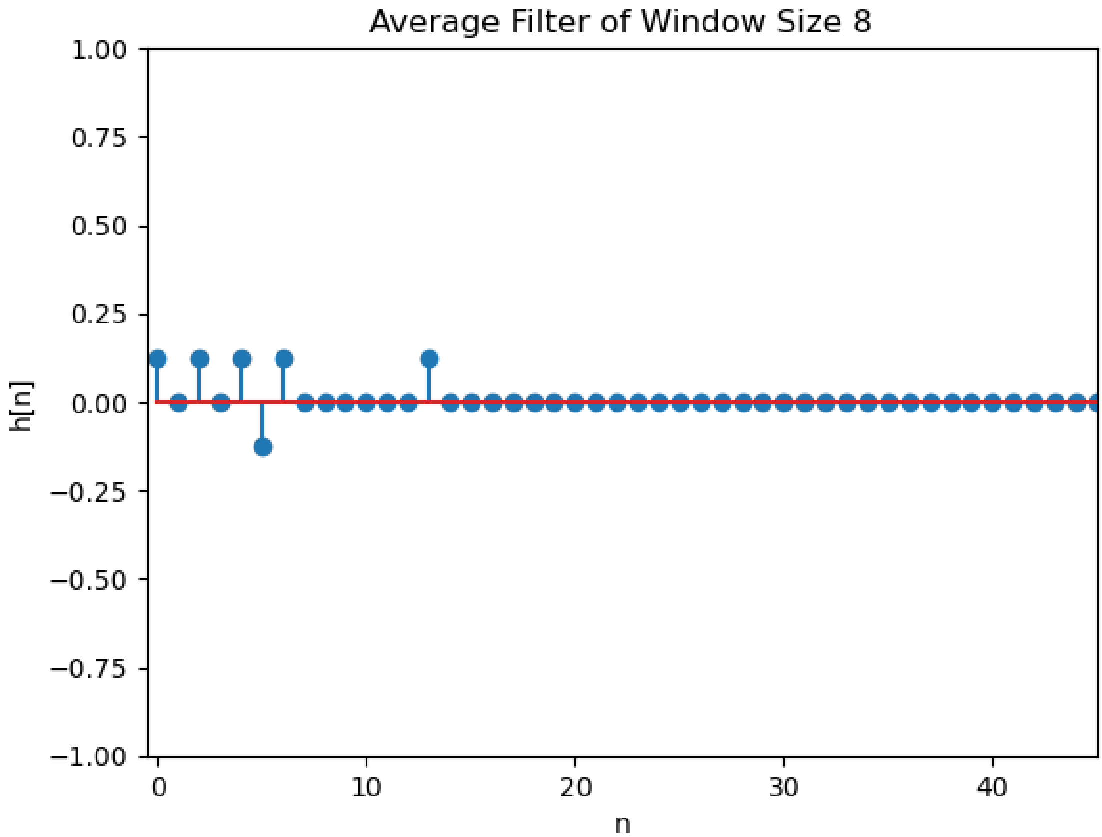
```
n = np.arange(0, 46, 1)
d = (n-6)==0
d2 = (n-5)==0
a = 1

x = np.cos((np.pi*n)/1) + d - d2

# original function
plt.figure()
plt.stem(n, x)
plt.title('Part F')
plt.axis([-0.5, 45, -2.5, 2.5])
plt.xlabel('n')
plt.ylabel('h[n]')

# N=4
filterN = 4
b = np.ones(filterN)/filterN
h = np.convolve(b, x)
plt.figure()
plt.stem(n, h[:len(n)])
plt.title('Moving Average Filter of Window Size 4')
plt.axis([-0.5, 45, -1.5, 1.5])
plt.xlabel('n')
plt.ylabel('h[n]')

# N=8
filterN = 8
b = np.ones(filterN)/filterN
h = np.convolve(b, x)
plt.figure()
plt.stem(n, h[:len(n)])
plt.title('Average Filter of Window Size 8')
plt.axis([-0.5, 45, -1, 1])
plt.xlabel('n')
plt.ylabel('h[n]')

# N=12
filterN = 12
b = np.ones(filterN)/filterN
h = np.convolve(b, x)
plt.figure()
plt.stem(n, h[:len(n)])
plt.title('Average Filter of Window Size 12')
plt.axis([-0.5, 45, -0.25, 0.25])
plt.xlabel('n')
```

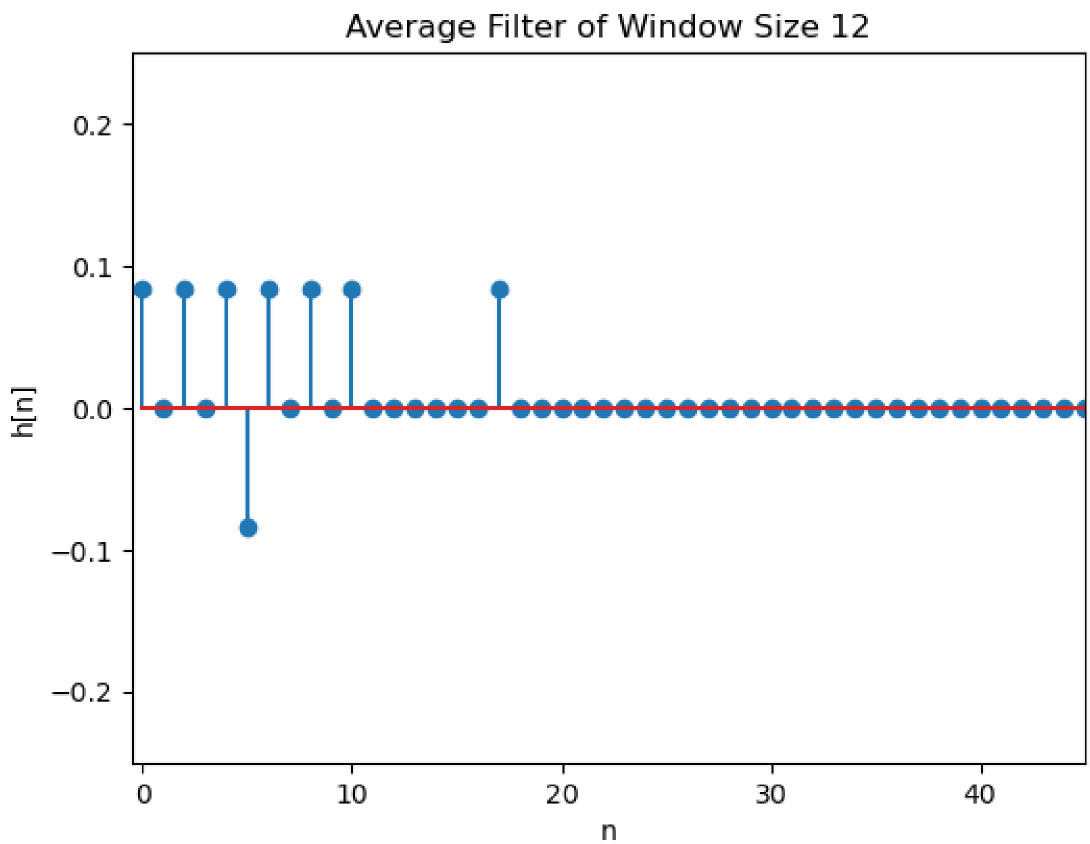
```
plt.ylabel('h[n]')
```

[1]: Text(0, 0.5, 'h[n]')




Moving Average Filter of Window Size 4
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
h[n]
0
10
20
30
40
n


Average Filter of Window Size 8
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
h[n]
0
10
20
30
40
n



[ ]:
```
#Comments on the behaviour of the filter:

#As the band size of the filter increases (the N value), the amplitude of the␣
↪function ends up decreasing.
#This is due to the fact that the filter takes an average over a larger number␣
↪of values, and in the meantime,
#the number of repetitive y-values and the number of y-values that can cancel␣
↪each other out ends up increasing
```

[6]:
```
filepath = "C:
↪\\Users\\zelen\\Desktop\\W2023\\ELE632\\lab2\\ELE632_Lab2_DaniloZelenovic_501032542_Section
↪ipynb"
!jupyter nbconvert --to pdf $filepath
```

```
[NbConvertApp] Converting notebook C:\Users\zelen\Desktop\W2023\ELE632\lab2\ELE6
32_Lab2_DaniloZelenovic_501032542_Section08.ipynb to pdf
[NbConvertApp] Support files will be in
ELE632_Lab2_DaniloZelenovic_501032542_Section08_files\
[NbConvertApp] Making directory
.\ELE632_Lab2_DaniloZelenovic_501032542_Section08_files
```

```
[NbConvertApp] Making directory
.\ELE632_Lab2_DaniloZelenovic_501032542_Section08_files
[NbConvertApp] Making directory
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[NbConvertApp] Making directory
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[NbConvertApp] Writing 48661 bytes to notebook.tex
[NbConvertApp] Building PDF
[NbConvertApp] Running xelatex 3 times: ['xelatex', 'notebook.tex', '-quiet']
[NbConvertApp] Running bibtex 1 time: ['bibtex', 'notebook']
[NbConvertApp] WARNING | b had problems, most likely because there were no
citations
[NbConvertApp] PDF successfully created
[NbConvertApp] Writing 179877 bytes to C:\Users\zelen\Desktop\W2023\ELE632\lab2\
ELE632_Lab2_DaniloZelenovic_501032542_Section08.pdf
```