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LAB2

Student experiment 1:

a) y[n]=x[n]-x[n-1]-x[n-2]

Linearity:

$x_1[n] \rightarrow y_1[n] = x_1[n] - x_1[n-1] - x_1[n-2]$

$x_2[n] \rightarrow y_2[n] = x_2[n] - x_2[n-1] - x_2[n-2]$

$A.y_1[n] + B.y_2[n] = A.(x_1[n] - x_1[n-1] - x_1[n-2]) + B(x_2[n] - x_2[n-1] - x_2[n-2]) \rightarrow (1)$

$x_3[n] = A.x_1[n] + B.x_2[n] \rightarrow y_3[n] = x_3[n] – x_3[n-1] – x_3[n-2]$

$y_3[n] = A.x_1[n] + B.x_2[n] - A.x_1[n-1] - B.x_2[n-1] - A.x_1[n-2] - B.x_2[n-2] \rightarrow (2)$

since (1) = (2) then $y_3[n] = A.y_1[n] + B.y_2[n]$ then the system is **linear**.

Time Invariance:

$x_1[n] \rightarrow y_1[n] = x_1[n] – x_1[n-1] – x_1[n-2] \rightarrow y_1[n-n_0] = x_1[n-n_0] – x_1[n-n_0-1] – x_1[n-n_0-2]$

$x_2[n] = x_1[n-n_0] \rightarrow y_2[n] = x_1[n-n_0] – x_1[n-n_0-1] – x_1[n-n_0-2]$

since $y_2[n] = y_1[n]$ then the system is **time invariant**.

y[n]=cos(x[n])

Linearity:

$x_1[n] \rightarrow y_1[n] = \cos(x_1[n])$

$x_2[n] \rightarrow y_2[n] = \cos(x_2[n])$

$A.y_1[n] + B.y_2[n] = A.\cos(x_1[n]) + B.\cos(x_2[n]) \rightarrow (1)$

$x_3[n] = A.x_1[n] + B.x_2[n] \rightarrow y_3[n] = \cos(x_3[n])$

$y_3[n] = \cos(A.x_1[n] + B.x_2[n]) \rightarrow (2)$

since (1) = (2) then $y_3[n] \neq A.y_1[n] + B.y_2[n]$ then the system is **nonlinear**.

Time Invariance:

$x_1[n] \rightarrow y_1[n] = \cos(x_1[n]) \rightarrow y_1[n-n_0] = \cos(x_1[n-n_0])$

$x_2[n] = x_1[n-n_0] \rightarrow y_2[n] = \cos(x_1[n]-n_0)$

since $y_2[n] = y_1[n]$ then the system is **time variant**.

$y[n]=nx[n]$

Linearity:

$x_1[n] \to y_1[n] = nx_1[n]$

$x_2[n] \to y_2[n] = nx_2[n]$

$A.y_1[n] + B.y_2[n] = A.nx_1[n] + B.nx_2[n] \to (1)$

$x_3[n] = A.x_1[n] + B.x_2[n] \to y_3[n] = nx_3[n]$

$y_3[n] = n(A.x_1[n] + B.x_2[n]) \to (2)$

since (1) = (2) then $y_3[n] = A.y_1[n] + B.y_2[n]$ then the system is **linear**.

Time Invariance:

$x_1[n] \to y_1[n] = nx_1[n] \to y_1[n-n_0] = (n-n_0).x_1[n-n_0]$

$x_2[n] = x_1[n-n_0] \to y_2[n] = n.x_1[n-n_0]$

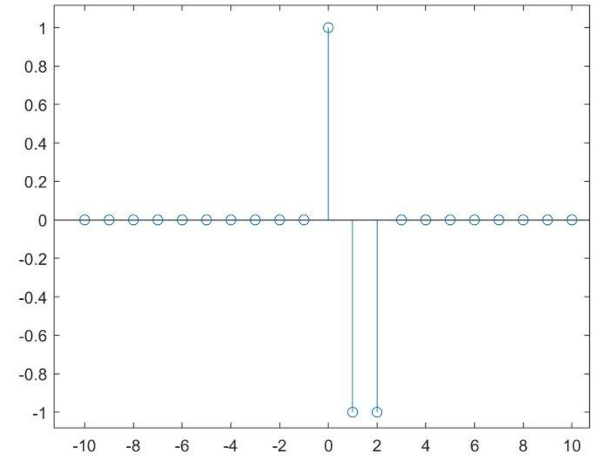
since $y_2[n] = y_1[n]$ then the system is **time variant**.

b) y[n]=x[n]-x[n-1]-x[n-2]

input = Delta(n)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];

>> y = zeros(1,length(x1));

>> for c=3:length(x1)

y(c) = x1(c)-x1(c-1)-x1(c-2)

end

>> stem(nx1, y)
```

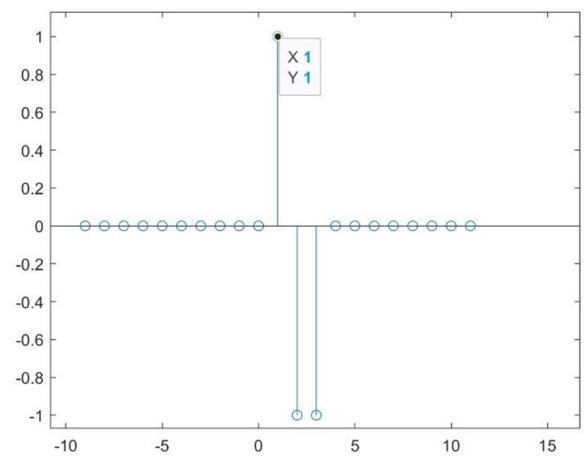
response



input = Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];

>> y = zeros(1,length(x1));

>> for c=3:length(x1)

y(c) = x1(c)-x1(c-1)-x1(c-2)

end

>> stem(nx1+1, y)
```

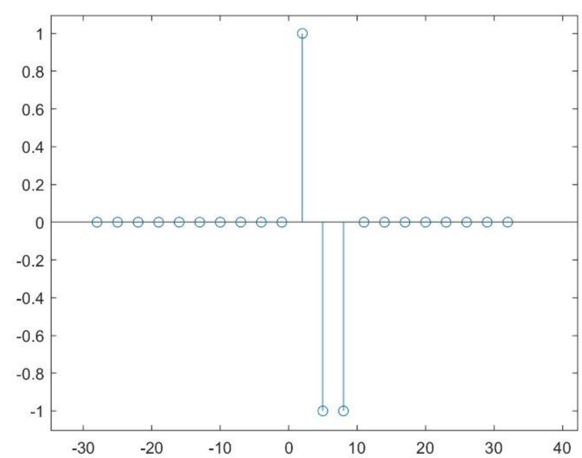
response



input = Delta(n)+2* Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];

>> y = zeros(1,length(x1));

>> for c=3:length(x1)

y(c) = x1(c)-x1(c-1)-x1(c-2)

end

>> stem(nx1+2*(nx1+1), y)
```

response

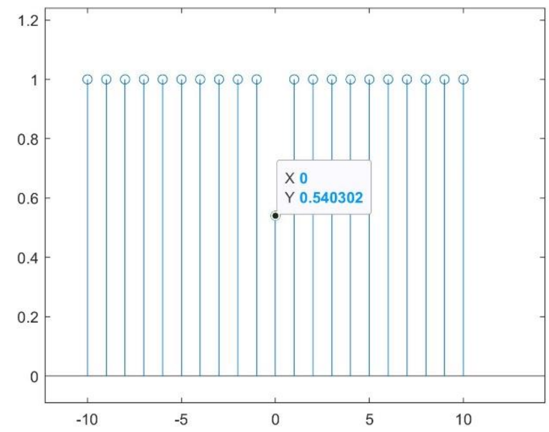


y[n]=cos(x[n])

input = Delta(n)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = cos(x1(c));
end
>> stem(nx1 ,y)
```

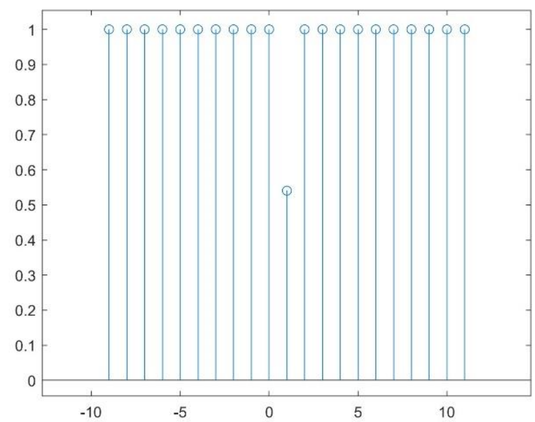
response



input = Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = cos(x1(c));
end
>> stem(nx1+1 ,y)
```

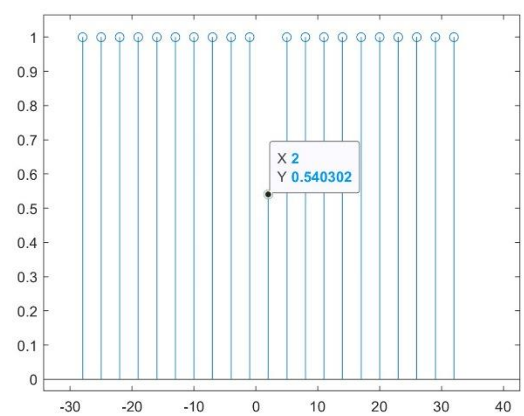
response



input = Delta(n)+2* Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = cos(x1(c));
end
>> stem(nx1+2*(nx1+1), y)
```

response

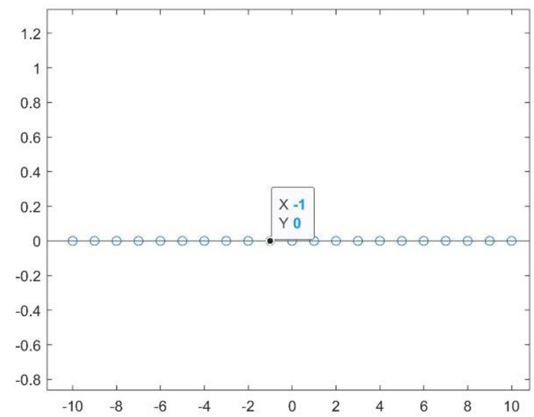


y[n]= nx[n]

input = Delta(n)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = nx1(c) * x1(c)
end
>> stem(nx1,y)
```

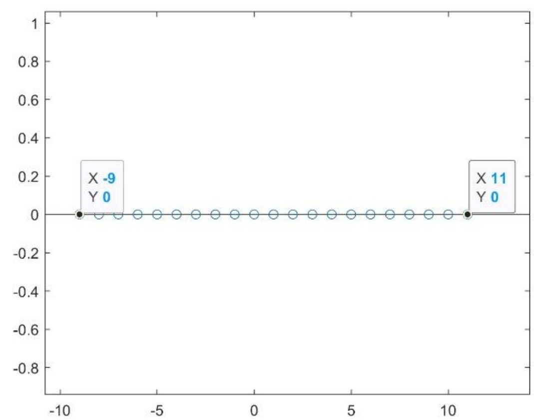
response



input = Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = nx1(c) * x1(c)
end
>> stem(nx1+1 ,y)
```

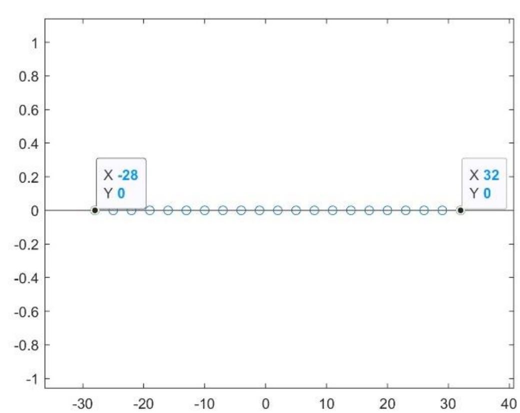
response



input = Delta(n)+2* Delta(n-1)

```
>> nx1=[-10:10], x1=[zeros(1,10) 1 zeros(1,10)];
>> y = zeros(1,length(x1));
>> for c=1:length(x1)
y(c) = nx1(c) * x1(c)
end
>> stem(nx1+2*(nx1+1), y)
```

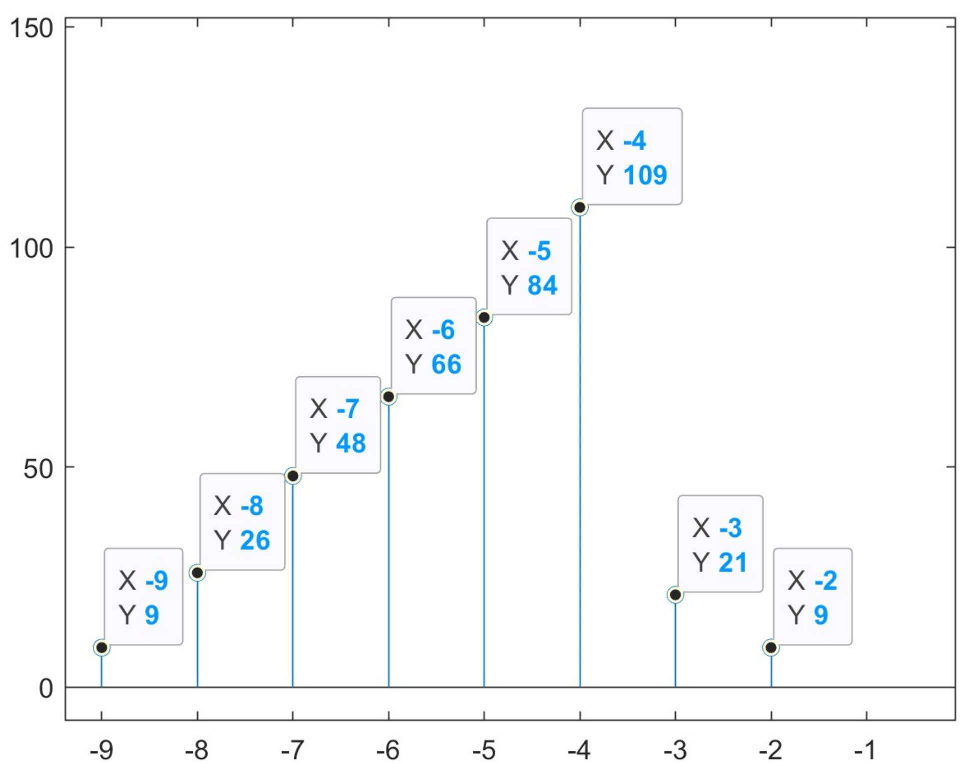
response



Student experiment 2:

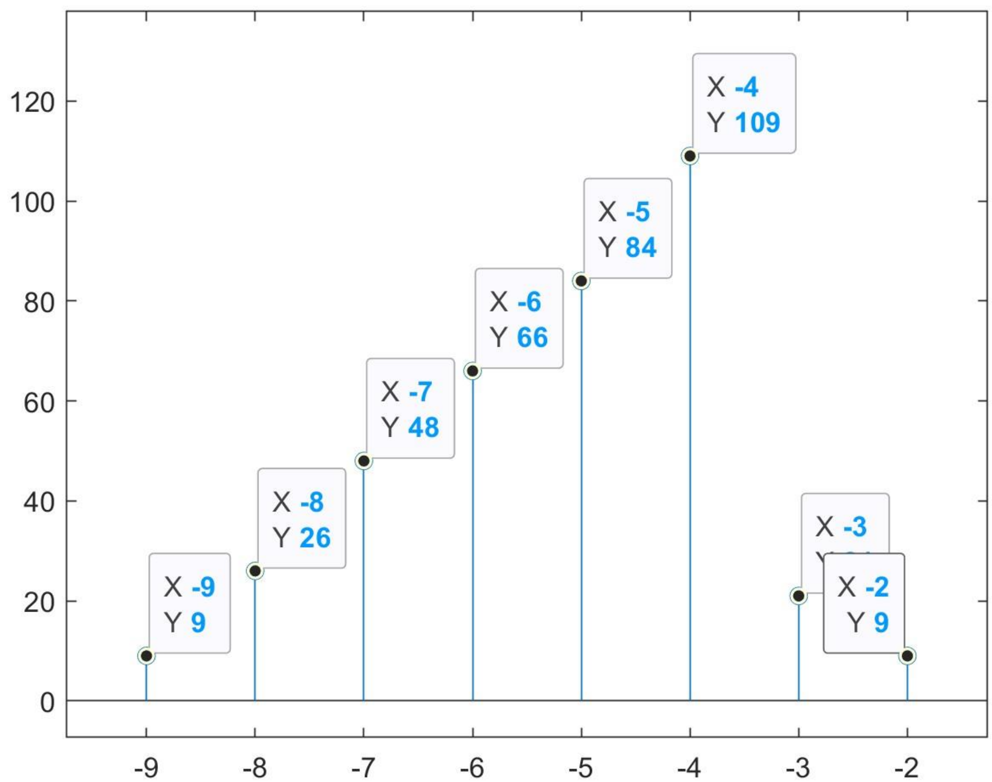
a)

```
>> nx=[-3 -2 -1];
>> x =[1 2 3];
>> nh=[-6 -5 -4 -3 -2 -1];
>> h =[9 8 5 32 5 3];
>> M=length(x);
>> N=length(h);
>> ny=[-9:-2]
>> y=zeros(1,M+N-1);
>> for u=1:(N)
x1=h(u)*[zeros(1,u-1) x zeros(1,length(y)-u-2)];
y=y+x1;
end
```



b)

```
>> nx=[-3 -2 -1];
>> x =[1 2 3];
>> nh=[-6 -5 -4 -3 -2 -1];
>> h =[9 8 5 32 5 3];
>> M=length(x);
>> N=length(h);
>> ny=[-9:-2]
>> y=conv(x,h);
```



Student experiment 3:

a) Inverse Fourier Series Code

```
function b=If_series(x)
N=length(x);
n=1:N;
b = zeros(1,N);
for k=1:N
b(k)=sum(x(k)*exp(-2*pi*i*k*n/N));
end
```

b) Fourier series of the three signals:

- $a_k = \frac{1}{T}\int_T x(t)\, e^{-jk\omega t}\, dt$
- $X(t) = \sum_{-\infty}^{\infty} a(k)\, e^{-jk\omega t}$

X = [1 2 3 4]

```
Fourier Coefficient:
ak =

  Columns 1 through 3

   2.5000 + 0.0000i  -0.5000 + 0.5000i  -0.5000 - 0.0000i

  Column 4

  -0.5000 - 0.5000i
```

```
X signal:
Xt =

  Columns 1 through 3

  -0.0000 + 0.0000i   0.0000 - 0.0000i  -0.0000 - 0.0000i

  Column 4

  -2.0000 - 2.0000i
```

X = [1 2 2 1]

```
Fourier Coefficient:
ak =

  Columns 1 through 3

   1.5000 + 0.0000i  -0.2500 - 0.2500i   0.0000 - 0.0000i

  Column 4

  -0.2500 + 0.2500i
```

```
X signal:
Xt =

  Columns 1 through 3

  -0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 0.0000i

  Column 4

  -1.0000 + 1.0000i
```

X = [0 1 2 -2 -1]

```
Fourier Coefficient:
ak =

  Columns 1 through 3

   0.0000 + 0.0000i   0.0000 - 0.8507i  -0.0000 + 0.5257i

  Columns 4 through 5

   0.0000 - 0.5257i  -0.0000 + 0.8507i
```

```
X signal:
Xt =

  Columns 1 through 3

   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.0000 + 0.0000i

  Columns 4 through 5

   0.0000 - 0.0000i  -0.0000 + 4.2533i
```

c) Fourier series algorithm:

x[n]=cos(2*pi*n*3/7)

take point n = 0 as the start point then: $\omega = 2\pi * \frac{3}{7}$, and since $T = \frac{2\pi}{\omega}$ then T = $\frac{2\pi}{2\pi * \frac{3}{7}} = \frac{7}{3}$

then take n = [0 : 7/3]

Analytical solution:

$$\cos(2\pi n * \frac{3}{7}) \rightarrow \frac{e^{\frac{6}{7}\pi n j} + e^{-\frac{6}{7}\pi n j}}{2}$$

Then $a_o = 0$
$a_6 = 0.5$
$a_{-6} = 0.5$

Fourier series algorithm on MATLAB:

```
>> n = [0:0.1:7/3]
>> x = cos(2*pi*n*3/7)
>> ak = f_series(x);
>> ak
ak =

  Columns 1 through 3

   0.0278 + 0.0000i   0.5045 + 0.0441i  -0.0098 - 0.0017i

  Columns 4 through 6

  -0.0035 - 0.0009i  -0.0018 - 0.0006i  -0.0011 - 0.0005i

  Columns 7 through 9

  -0.0007 - 0.0003i  -0.0005 - 0.0003i  -0.0003 - 0.0002i

  Columns 10 through 12

  -0.0003 - 0.0001i  -0.0002 - 0.0001i  -0.0002 - 0.0000i

  Columns 13 through 15

  -0.0002 - 0.0000i  -0.0002 + 0.0000i  -0.0002 + 0.0001i

  Columns 16 through 18

  -0.0003 + 0.0001i  -0.0003 + 0.0002i  -0.0005 + 0.0003i

  Columns 19 through 21

  -0.0007 + 0.0003i  -0.0011 + 0.0005i  -0.0018 + 0.0006i

  Columns 22 through 24

  -0.0035 + 0.0009i  -0.0098 + 0.0017i   0.5045 - 0.0441i
```

x[n]= sin(2*pi*n*3/7)

take point n = 0 as the start point then: $\omega = 2\pi * \frac{3}{7}$, and since $T = \frac{2\pi}{\omega}$ then T = $\frac{2\pi}{2\pi * \frac{3}{7}} = \frac{7}{3}$

then take n = [0 : 7/3]

<u>Analytical solution:</u>

$$\cos(2\pi n * \frac{3}{7}) \to \frac{e^{\frac{6}{7}\pi n j} - e^{-\frac{6}{7}\pi n j}}{2j}$$

Then a_o = 0
a_6 = 1/(2j)
a_{-6} = -1/(2j)

<u>Fourier series algorithm on MATLAB:</u>

```
>> n = [0:0.1:7/3]
>> x = sin(2*pi*n*3/7)
>> ak = f_series(x);
>> ak
ak =

  Columns 1 through 3

  -0.0012 + 0.0000i   0.0417 - 0.4905i  -0.0046 + 0.0190i

  Columns 4 through 6

  -0.0041 + 0.0102i  -0.0039 + 0.0069i  -0.0038 + 0.0051i

  Columns 7 through 9

  -0.0038 + 0.0039i  -0.0038 + 0.0029i  -0.0038 + 0.0022i

  Columns 10 through 12

  -0.0038 + 0.0016i  -0.0038 + 0.0010i  -0.0038 + 0.0005i

  Columns 13 through 15

  -0.0038 + 0.0000i  -0.0038 - 0.0005i  -0.0038 - 0.0010i

  Columns 16 through 18

  -0.0038 - 0.0016i  -0.0038 - 0.0022i  -0.0038 - 0.0029i

  Columns 19 through 21

  -0.0038 - 0.0039i  -0.0038 - 0.0051i  -0.0039 - 0.0069i

  Columns 22 through 24

  -0.0041 - 0.0102i  -0.0046 - 0.0190i   0.0417 + 0.4905i
```

x[n]= exp(j*2*pi*n*3/7)

take point n = 0 as the start point then: $\omega = 2\pi * \frac{3}{7}$, and since $T = \frac{2\pi}{\omega}$ then T = $\frac{2\pi}{2\pi * \frac{3}{7}} = \frac{7}{3}$

then take n = [0 : 7/3]

Analytical solution:

$$e^{j\frac{6}{7}\pi n}$$

Then $a_o = 0$
$a_6 = 1$

Fourier series algorithm on MATLAB:

```
>> n = [0:0.1:7/3]
>> x = exp(j*2*pi*n*3/7)
>> ak = f_series(x);
ak =

  Columns 1 through 3

   0.0278 - 0.0012i   0.9950 + 0.0858i  -0.0288 - 0.0063i

  Columns 4 through 6

  -0.0138 - 0.0050i  -0.0087 - 0.0045i  -0.0062 - 0.0043i

  Columns 7 through 9

  -0.0046 - 0.0042i  -0.0034 - 0.0041i  -0.0025 - 0.0040i

  Columns 10 through 12

  -0.0018 - 0.0039i  -0.0012 - 0.0039i  -0.0007 - 0.0038i

  Columns 13 through 15

  -0.0002 - 0.0038i   0.0003 - 0.0037i   0.0008 - 0.0037i

  Columns 16 through 18

   0.0013 - 0.0036i   0.0019 - 0.0036i   0.0025 - 0.0035i

  Columns 19 through 21

   0.0032 - 0.0035i   0.0040 - 0.0034i   0.0051 - 0.0033i

  Columns 22 through 24

   0.0067 - 0.0031i   0.0092 - 0.0029i   0.0140 - 0.0025i
```