Bilkent University

Electrical and Electronics Department

EE321-02 Lab 1 Report:

03/10/2024

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Introduction:

This lab consisted of 15 parts. We plotted discrete sinusoidal signals with varying amplitude and frequencies in MATLAB. Before I start answering the questions, I would like to introduce you the 3 functions I've written and used during this lab:

The function "findint.m" takes a rational number as an input and gives the smallest integer multiple of that rational number as an output. **(Appendix 1)**

The function "findperiod.m" takes ω (normalized frequency) in radians as input and gives the unitless fundamental period for that ω. Beware that this output T is always an integer since we are dealing with discrete signals. **(Appendix 2)**

The function "disccosgenerator.m" takes the amplitude, frequency and phase shift parameters as inputs and gives a 1*128 vector which is the discrete cosine output as well as a fundamental period output for the specific input signal. **(Appendix 3)**

Q1:

Computers run with data registers which can't comprehend a continuous signal. Computers work with digital discrete signals.

a)

I used the code in **Appendix 5** to create a .txt file **(Appendix 4)** to store the elements of the discrete cosine signal. Then I extracted each element from that .txt file. Here are the desired elements mentioned in the question: **(Figure 1.a)**

```
dlmwrite('y1.txt', y1, 'delimiter', ' ');
y1_2 = dlmread('y1.txt');

[y1(4), y1_2(4), y1(8), y1_2(8), y1(115), y1_2(115), y1(128), y1_2(128)]

ans =

   -0.4614   -0.4614   -2.9295   -2.9295   -2.9936   -2.9936   -1.5203   -1.5203
```

Figure 1.a: x1[3], x1[7], x1[114] and x1[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.13*pi [rad]: **(Figure 1.b)**

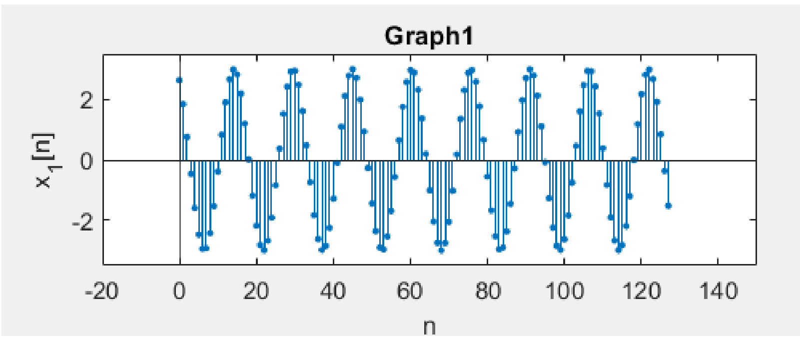

Figure 1.b: x1[n] = 3*cos(0.13*pi*n+0.5) ;where n ∈ [0,127]

Q2:

a)

The same code in part 1-a was used for writing and extracting the signal "x2[n] = cos(2.2*pi*n)". Here are the desired elements mentioned in the question **(Figure 2.a)**:

```
[y2(4), y2_2(4), y2(8), y2_2(8), y2(115), y2_2(115), y2(128), y2_2(128)]

ans =

   -0.3090   -0.3090   -0.3090   -0.3090   -0.8090   -0.8090   -0.3090   -0.3090
```

Figure 2.a: x2[3], x2[7], x2[114] and x2[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 2.2*pi [rad] **(Figure 2.b)**:

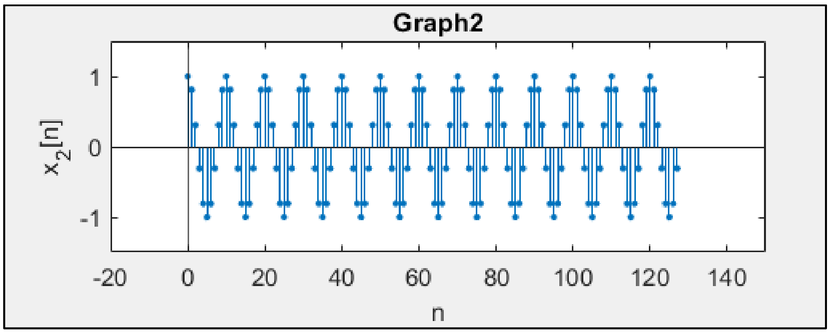

Figure 2.b: x2[n] = cos(2.2*pi*n) ;where n ∈ [0,127]

Q3:

a)

The same code in part 1-a was used for writing and extracting the signal “x3[n] = cos(-1.8*pi*n)”. Here are the desired elements mentioned in the question **(Figure 3.a)**:

```
[y3(4), y3_2(4), y3(8), y3_2(8), y3(115), y3_2(115), y3(128), y3_2(128)]

ans =

   -0.3090   -0.3090   -0.3090   -0.3090   -0.8090   -0.8090   -0.3090   -0.3090
```

Figure 3.a: x3[3], x3[7], x3[114] and x3[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value -1.8*pi [rad] **(Figure 3.b)**:

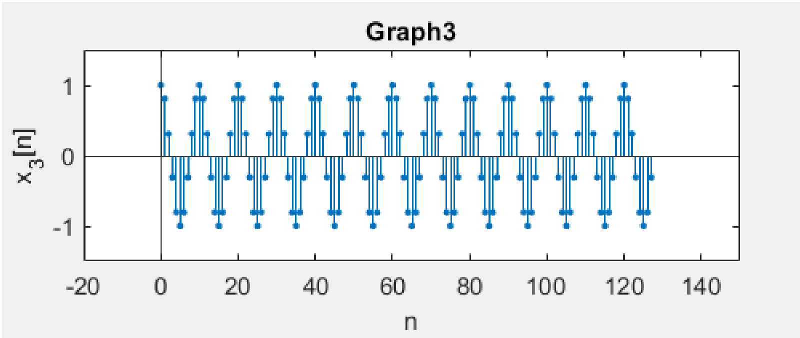

Figure 3.b: x3[n] = cos(-1.8*pi*n) ;where n ∈ [0,127]

Comments: The discrete x2[n] and x3[n] signals are identical. Because of (1) and (2):

$$\cos(\omega n + \theta) = \cos(\omega n + \theta + 2\pi \cdot k)$$; where n,k ∈ Z **(1)**

$$\cos(2.2 \cdot \pi \cdot n) = \cos(-1.8 \cdot \pi \cdot n + 2 \cdot 2\pi \cdot n)$$; where n ∈ Z (2)

Q4:

a)

The same code in part 1-a was used for writing and extracting the signal "x4[n] = cos(0.26*pi*n)". Here are the desired elements mentioned in the question **(Figure 4.a)**:

```
[y4(4), y4_2(4), y4(8), y4_2(8), y4(115), y4_2(115), y4(128), y4_2(128)]

ans =

   -0.7705   -0.7705    0.8443    0.8443    0.4258    0.4258   -0.9980   -0.9980
```

Figure 4.a: x4[3], x4[7], x4[114] and x4[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.26*pi [rad] **(Figure 4.b)**:

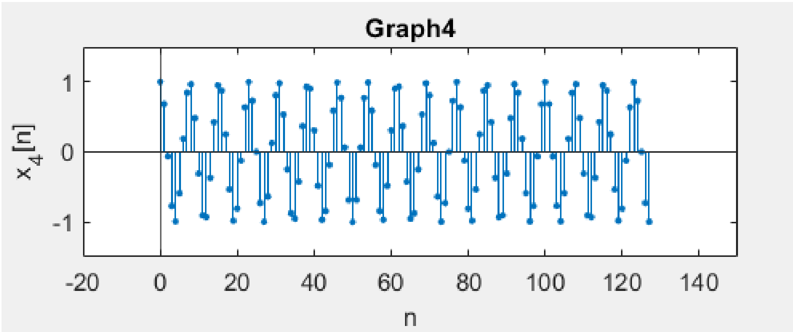

Figure 4.b: x4[n] = cos(0.26*pi*n) ;where n ∈ [0,127]

Q5:

a)

The same code in part 1-a was used for writing and extracting the signal “x5[n] = cos(0.26*pi*n+0.7)”. Here are the desired elements mentioned in the question **(Figure 5.a)**:

```
[y5(4), y5_2(4), y5(8), y5_2(8), y5(115), y5_2(115), y5(128), y5_2(128)]

ans =

   -1.0000    -1.0000     0.9910     0.9910     0.9086     0.9086    -0.7229    -0.7229
```

Figure 5.a: x5[3], x5[7], x5[114] and x5[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.26*pi [rad] **(Figure 5.b)**:

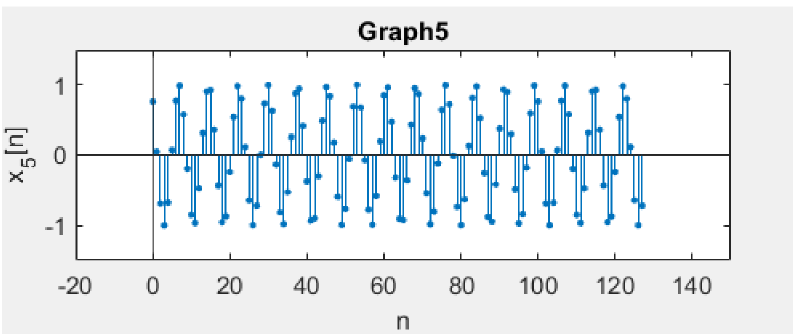

Figure 5.b: x5[n] = cos(0.26*pi*n+0.7) ;where n ∈ [0,127]

Comments: The discrete signals x4[n] and x5[n] have the same ω values but there is a phase shift between them. We are dealing with discrete signals and both the signals have different values in different positions. They are completely different from one another.

Q6:

a)

The same code in part 1-a was used for writing and extracting the signal "x6[n] = cos(0.01*pi*n)". Here are the desired elements mentioned in the question **(Figure 6.a)**:

```
[y6(4), y6_2(4), y6(8), y6_2(8), y6(115), y6_2(115), y6(128), y6_2(128)]

ans =

    0.9956    0.9956    0.9759    0.9759   -0.9048   -0.9048   -0.6613   -0.6613
```

Figure 6.a: x6[3], x6[7], x6[114] and x6[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.01*pi [rad] **(Figure 6.b)**:

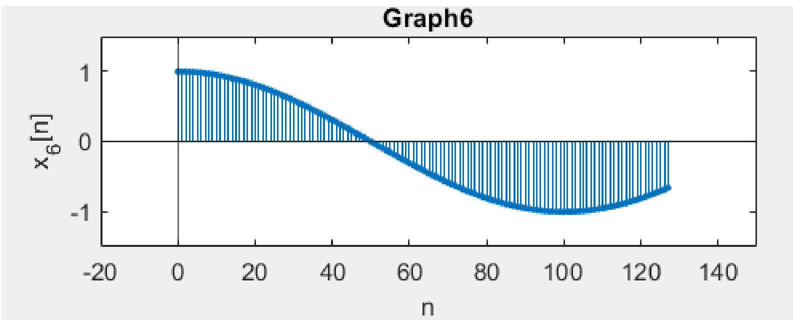

Figure 6.b: x6[n] = cos(0.01*pi*n) ;where n ∈ [0,127]

Q7:

a)

The same code in part 1-a was used for writing and extracting the signal "x7[n] = cos(0.39*pi*n)". Here are the desired elements mentioned in the question **(Figure 7.a)**:

```
[y7(4), y7_2(4), y7(8), y7_2(8), y7(115), y7_2(115), y7(128), y7_2(128)]

ans =

   -0.8607   -0.8607   -0.6613   -0.6613    0.1253    0.1253    0.0941    0.0941
```

Figure 7.a: x7[3], x7[7], x7[114] and x7[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.39*pi [rad] **(Figure 7.b)**:

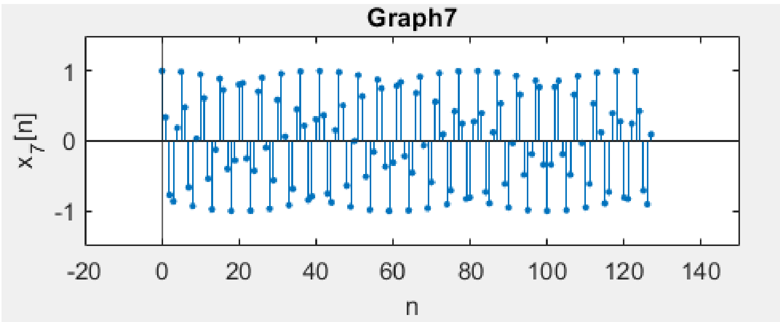

Figure 7.b: x7[n] = cos(0.39*pi*n) ;where n ∈ [0,127]

Q8:

a)

The same code in part 1-a was used for writing and extracting the signal "x8[n] = cos(pi*n)". Here are the desired elements mentioned in the question **(Figure 8.a)**:

```
[y8(4), y8_2(4), y8(8), y8_2(8), y8(115), y8_2(115), y8(128), y8_2(128)]

ans =

    -1    -1    -1    -1     1     1    -1    -1
```

Figure 8.a: x8[3], x8[7], x8[114] and x8[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value pi [rad] **(Figure 8.b)**:

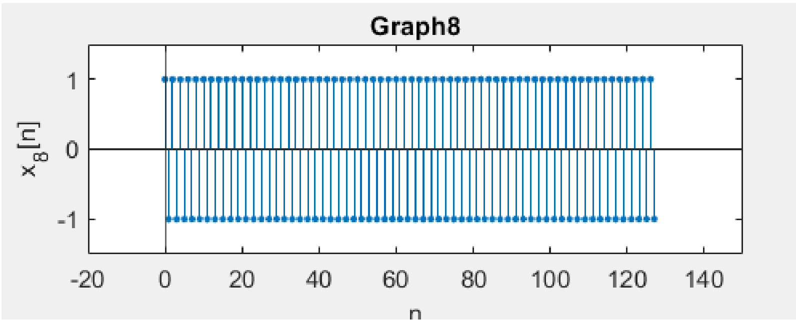

Figure 8.b: x8[n] = cos(pi*n) ;where n ∈ [0,127]

Q9:

a)

The same code in part 1-a was used for writing and extracting the signal "x9[n] = cos(1.08*pi*n)". Here are the desired elements mentioned in the question **(Figure 9.a)**:

```
[y9(4), y9_2(4), y9(8), y9_2(8), y9(115), y9_2(115), y9(128), y9_2(128)]

ans =

   -0.7290   -0.7290    0.1874    0.1874   -0.9298   -0.9298   -0.8763   -0.8763
```

Figure 9.a: x9[3], x9[7], x9[114] and x9[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 1.08*pi [rad] **(Figure 9.b)**:

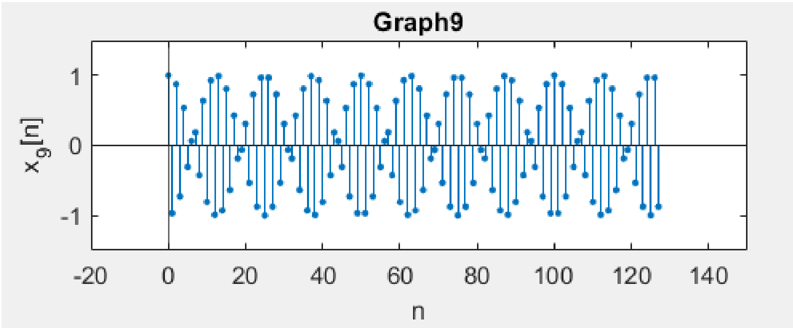

Figure 9.b: x9[n] = cos(1.08*pi*n) ;where n ∈ [0,127]

Q10:

a)

The same code in part 1-a was used for writing and extracting the signal "x10[n] = cos(0.92*pi*n)". Here are the desired elements mentioned in the question **(Figure 10.a)**:

```
[y10(4), y10_2(4), y10(8), y10_2(8), y10(115), y10_2(115), y10(128), y10_2(128)]

ans =

   -0.7290   -0.7290    0.1874    0.1874   -0.9298   -0.9298   -0.8763   -0.8763
```

Figure 10.a: x10[3], x10[7], x10[114] and x10[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.92*pi [rad] **(Figure 10.b)**:

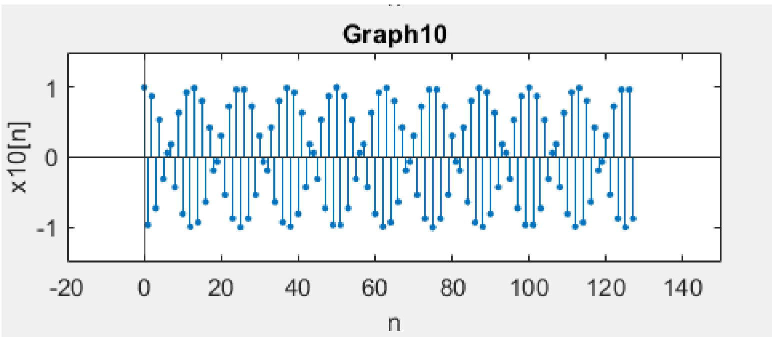

Figure 10.b: x10[n] = cos(0.92*pi*n) ;where n ∈ [0,127]

Comments: The signals x9[n] and x10[n] are identical to each other. Even though their respective ω values are different, since we are dealing with discrete signals, they are identical. The case here happens when we observe these two signals **(Figures 10.c&10.d)**:

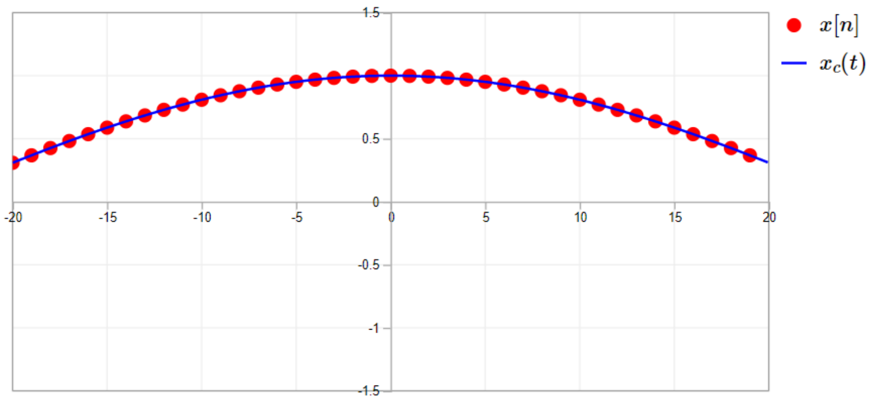

Figure 10.c: Low frequency continuous and sampled signals

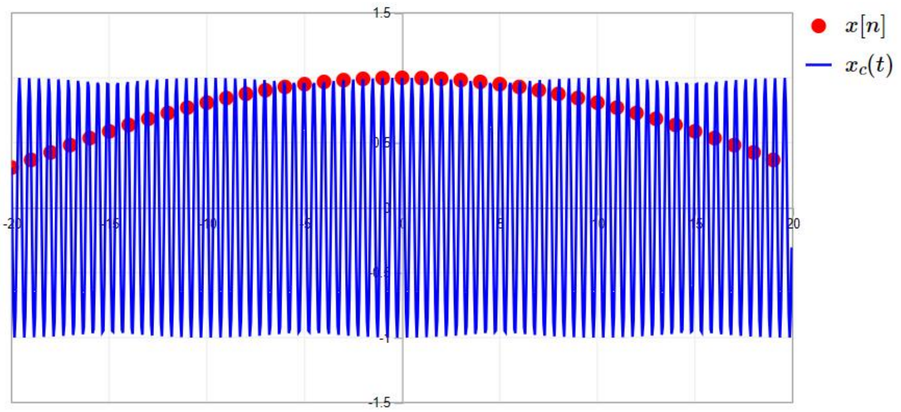

Figure 10.d: High frequency continuous and sampled signals

Comments(cont'd): The figures 10.c and 10.d show two different continuous signals with one of them being a high frequency signal and one of them being a low frequency signal. When you sample these signals to obtain a discrete signal, what you end up with is two identical discrete signals. This happens because of aliasing. Aliasing happens when you try to sample a high frequency signal with a not-so-high sampling rate. What happened in our case with x9[n] and x10[n] are exactly the same with this phenomenon with signals shown in figures 10.c and 10.d being an exaggerated example.

Q11:

a)

The same code in part 1-a was used for writing and extracting the signal "x11[n] = cos(n)". Here are the desired elements mentioned in the question **(Figure 11.a)**:

```
[y11(4), y11_2(4), y11(8), y11_2(8), y11(115), y11_2(115), y11(128), y11_2(128)]

ans =

   -0.9900   -0.9900    0.7539    0.7539    0.6195    0.6195    0.2324    0.2324
```

Figure 11.a: x11[3], x11[7], x11[114] and x11[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 1 [rad] **(Figure 11.b)**:

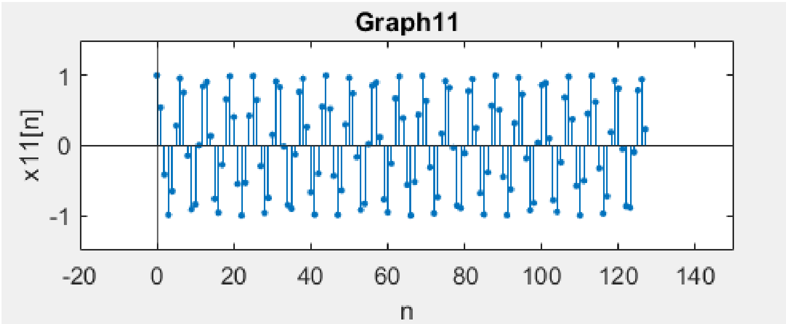

Figure 11.b: x11[n] = cos(n) ;where n ∈ [0,127]

Q12:

a)

The same code in part 1-a was used for writing and extracting the signal “x12[n] = cos(0.9*n+0.3)”. Here are the desired elements mentioned in the question **(Figure 12.a)**:

```
[y12(4), y12_2(4), y12(8), y12_2(8), y12(115), y12_2(115), y12(128), y12_2(128)]

ans =

   -0.9900   -0.9900    0.9502    0.9502   -0.7161   -0.7161    0.0681    0.0681
```

Figure 12.a: x12[3], x12[7], x12[114] and x12[127]

As you can see in the answer both the original and the extracted vectors have the same values.

b)

Here is the graph of our discrete signal where ω has the value 0.9 [rad] **(Figure 12.b)**:

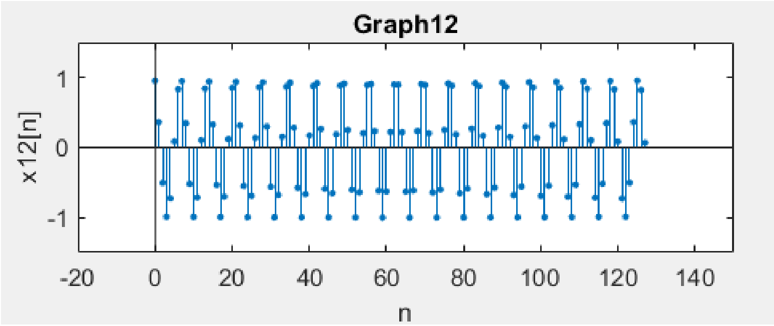

Figure 12.b: x12[n] = cos(0.9*n+0.3) ;where n ∈ [0,127]

Here is a table for the desired values of signals from Q1 to Q12: **(Table 1)**

	x[3]	x[7]	x[114]	x[127]
x1[n]	-0.4614	-2.9295	-2.9936	-1.5203
x2[n]	-0.3090	-0.3090	-0.8090	-0.3090
x3[n]	-0.3090	-0.3090	-0.8090	-0.3090
x4[n]	-0.7705	0.8443	0.4258	-0.9980
x5[n]	-1	0.9910	0.9086	-0.7229
x6[n]	0.9956	0.9759	-0.9048	-0.6613
x7[n]	-0.8607	-0.6613	0.1253	0.0941
x8[n]	-1	-1	1	-1
x9[n]	-0.7290	0.1874	-0.9298	-0.8763
x10[n]	-0.7290	0.1874	-0.9298	-0.8763
x11[n]	-0.9900	0.7539	0.6195	0.2324
x12[n]	-0.9900	0.9502	-0.7161	0.0681

Table 1

Q13:

Here are the fundamental periods for each of the signals from Q1 to Q12 **(Figure 13)**:

1	2	3	4	5	6	7	8	9	10	11	12
200	10	10	100	100	200	200	2	50	50	NaN	NaN

Figure 13: Fundamental Periods for each Signal

The x11[n] and x12[n] signals are not periodic because there is no such N that successfully completes (3) for x11[n] and x12[n].

$$x[n+N] = x[n] \qquad \textbf{(3)}$$

The reason for this being is because no integer k can be found in (4); where T is the fundamental period, ω is the normalized frequency, and k is the smallest integer which makes T also an integer.

$$T = \frac{2\pi}{\omega} \cdot k \text{ ;where k,T} \in \text{Z} \quad \textbf{(4)}$$

Q14:

ω must satisfy (5) to have a periodic discrete cosine and the corresponding fundamental period. Beware that k and T are integers. If there is no such k and T values can be found for an arbitrary ω; then the discrete cosine will not be periodic.

$$\omega = \frac{2\pi \cdot k}{T} \text{ ;where k,T} \in \text{Z} \qquad \textbf{(5)}$$

Another implementation of condition in (5) can be seen in (6). ω should be a value that makes (6) a rational number.

$$\frac{2\pi}{\omega} \qquad \textbf{(6)}$$

Q15:

The periodicity properties of discrete cosine signals and continuous cosine signals differ due to the nature of how time is represented and sampled in each domain.

In continuous signals, period is just inverse frequency with unit time. It can be any real number. Whereas, in discrete signals, the period is unitless and it should be an integer value. Also, in continuous signals, period just depends on frequency whereas, in discrete signals a number of factors and parameters play in determining the fundamental period of the discrete signal.

Conclusion

This lab consisted of 15 different questions. We plotted discrete sinusoidal signals with varying amplitude and frequencies in MATLAB.

I believe this lab was very helpful both in understanding the nature of discrete signals as well as some fundamental MATLAB general knowledge. I think this lab will help us in our exams, since it helped us visualize clearly what we were learning in the lectures.

Appendices:

1. https://github.com/fmcetin7/Bilkent-EEE-321/blob/main/lab%201/findint.m
2. https://github.com/fmcetin7/Bilkent-EEE-321/blob/main/lab%201/findperiod.m
3. https://github.com/fmcetin7/Bilkent-EEE-321/blob/main/lab%201/disccosgenerator.m
4. https://github.com/fmcetin7/Bilkent-EEE-321/blob/main/lab%201/y1.txt
5. https://github.com/fmcetin7/Bilkent-EEE-321/blob/main/lab%201/question1a.m
6.