

Lecture 1: Introduction to Signals

Practice Exercises

Konstantinos Chatzilygeroudis
costashatz@upatras.gr

19 February 2026

1 Coding Exercises

Question 1.1

Let $x(t) = 2\cos(t)$. On the interval $t \in [0, 4\pi]$, plot on the same figure:

$$x(t), \quad x(t - \pi), \quad x(2t), \quad -\frac{1}{2}x(t).$$

Then answer:

1. Which curves are time-shifted? By how much and in which direction?
2. Which curve is time-compressed? How can you tell from the number of oscillations?
3. Which curve is amplitude-inverted and attenuated? Explain from the formula.

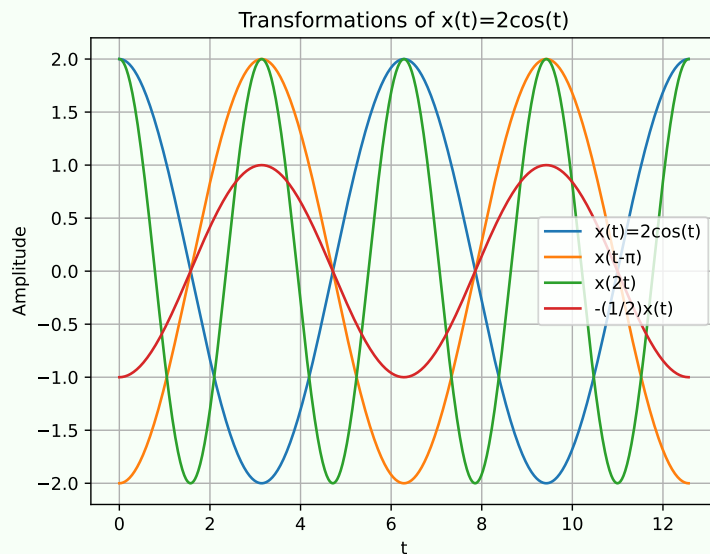
Use 3000 points in the interval $[0, 4\pi]$ for a smooth plot.

Solution (Code)

```
1 import numpy as np
2 import matplotlib.pyplot as plt
3
4 t = np.linspace(0, 4*np.pi, 3000)
5 x = 2*np.cos(t)
6
7 x_shift = 2*np.cos(t - np.pi)      # x(t-π)
8 x_comp = 2*np.cos(2*t)              # x(2t)
9 x_amp = -0.5*x                      # -(1/2)x(t)
10
11 plt.figure()
12 plt.plot(t, x, label="x(t)=2cos(t)")
13 plt.plot(t, x_shift, label="x(t-π)")
14 plt.plot(t, x_comp, label="x(2t)")
15 plt.plot(t, x_amp, label="-(1/2)x(t)")
16 plt.xlabel("t")
17 plt.ylabel("Amplitude")
18 plt.title("Transformations of x(t)=2cos(t)")
19 plt.grid(True)
20 plt.legend()
21 plt.show()
```

Solution

Plot:



Answers:

1. $x(t - \pi)$ is shifted to the right by π (a delay), because replacing t with $t - \pi$ moves features later in time.
2. $x(2t)$ is time-compressed because the argument changes twice as fast; over the same t -interval it completes twice as many oscillations.
3. $-(1/2)x(t)$ flips the sign (vertical inversion) due to the minus sign, and reduces amplitude by factor $1/2$ (attenuation).

Question 1.2

Define the discrete time signal

$$x[n] = 2n \cos\left(\frac{\pi}{4}n\right), \quad n = -20, \dots, 20.$$

Plot (using a stem plot) the following sequences on separate subplots or separate figures:

$$x[n], \quad x[n - 3], \quad x[-n], \quad 2x[n].$$

Then answer:

1. Which operation corresponds to delaying by 3 samples?
2. Which operation corresponds to time reversal?

Solution (Code)

```

1 import numpy as np
2 import matplotlib.pyplot as plt
3
4 n = np.arange(-20, 21)
5 x = 2*n*np.cos((np.pi/4)*n)
6
7 x_delay = 2*(n-3)*np.cos((np.pi/4)*(n-3)) # x[n-3]
8 x_rev = 2*(-n)*np.cos((np.pi/4)*(-n)) # x[-n]
9 x_amp = 2*x
10
11 plt.figure()
12 plt.stem(n, x)
13 plt.title("x[n]")

```

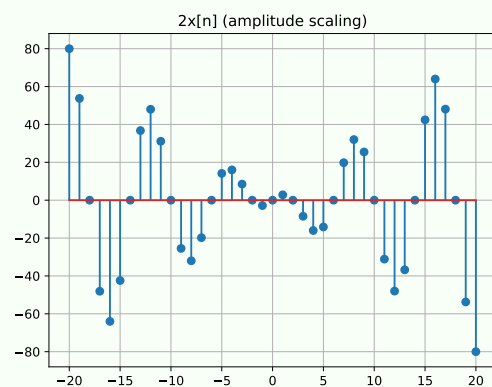
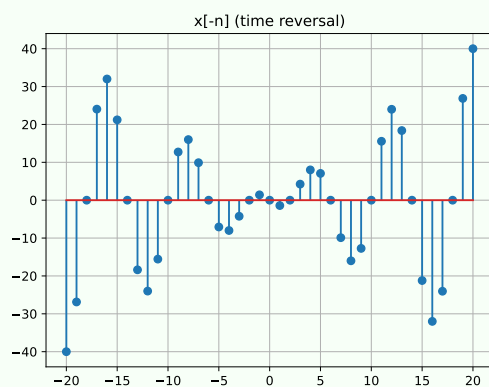
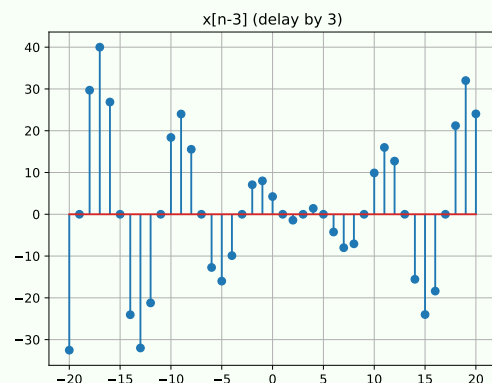
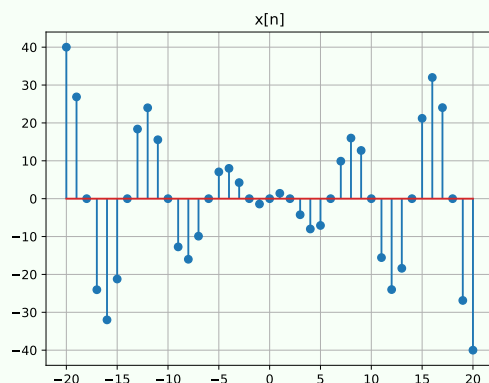
```

14 plt.grid(True)
15
16 plt.figure()
17 plt.stem(n, x_delay)
18 plt.title("x[n-3] (delay by 3)")
19 plt.grid(True)
20
21 plt.figure()
22 plt.stem(n, x_rev)
23 plt.title("x[-n] (time reversal)")
24 plt.grid(True)
25
26 plt.figure()
27 plt.stem(n, x_amp)
28 plt.title("2x[n] (amplitude scaling)")
29 plt.grid(True)
30
31 plt.show()

```

Solution

Plots:



Answers:

1. $x[n-3]$ is a delay by 3 samples (features move right on the n -axis).
2. $x[-n]$ mirrors the sequence about $n = 0$.