# Instituto Politécnico Nacional

## Escuela Superior de Cómputo

Proyecto 1

MatLab

Materia:

Teoría de Señales y Comunicaciones

Grupo:

3CV14

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Fecha:

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# Contenido

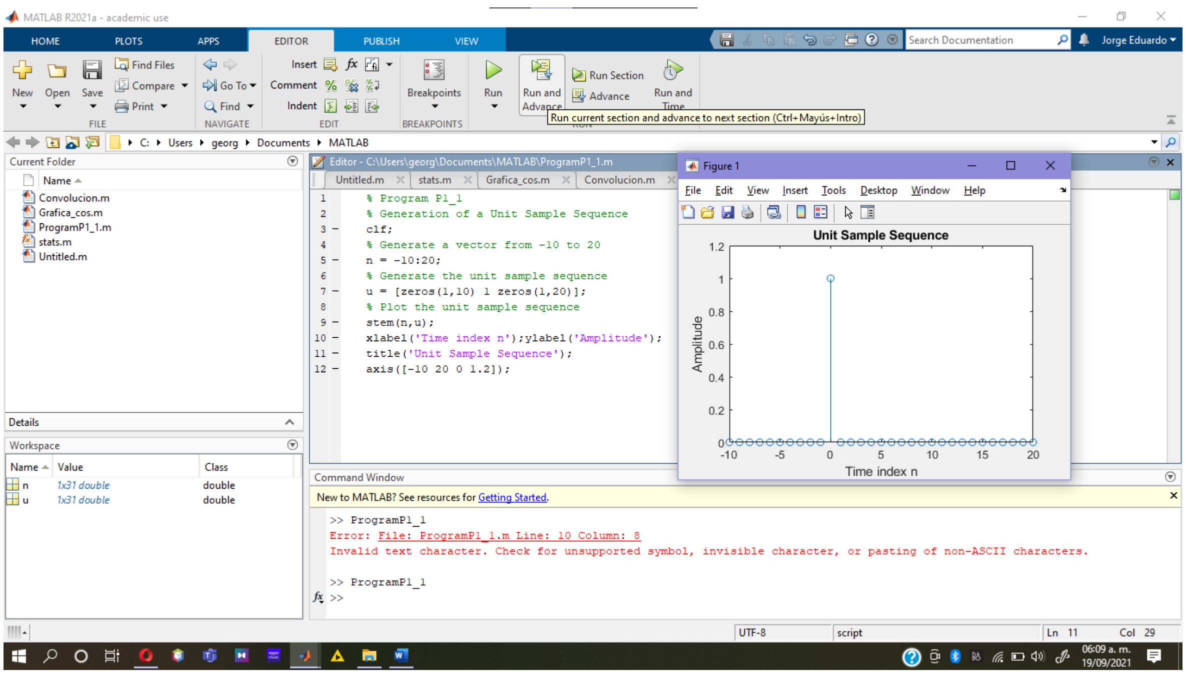
# A. Project 1.1 Unit Sample and Unit Step Sequences

Program P1 1 can be used to generate and plot a unit sample sequence:

```
% Program P1_1
% Generation of a Unit Sample Sequence
clf;
% Generate a vector from -10 to 20
n = -10:20;
% Generate the unit sample sequence
u = [zeros(1,10) 1 zeros(1,20)];
% Plot the unit sample sequence
stem(n,u);
xlabel('Time index n');ylabel('Amplitude');
title('Unit Sample Sequence');
axis([-10 20 0 1.2]);
```

- **Questions:**

1) Q1.1 Run Program P1 1 to generate the unit sample sequence u[n] and display it.




2) Q1.2 What are the purposes of the commands clf, axis, title, xlabel, and ylabel?

Clf sirve para borrar la figura actual.

Axis controla la escala y apariencia de los ejes.

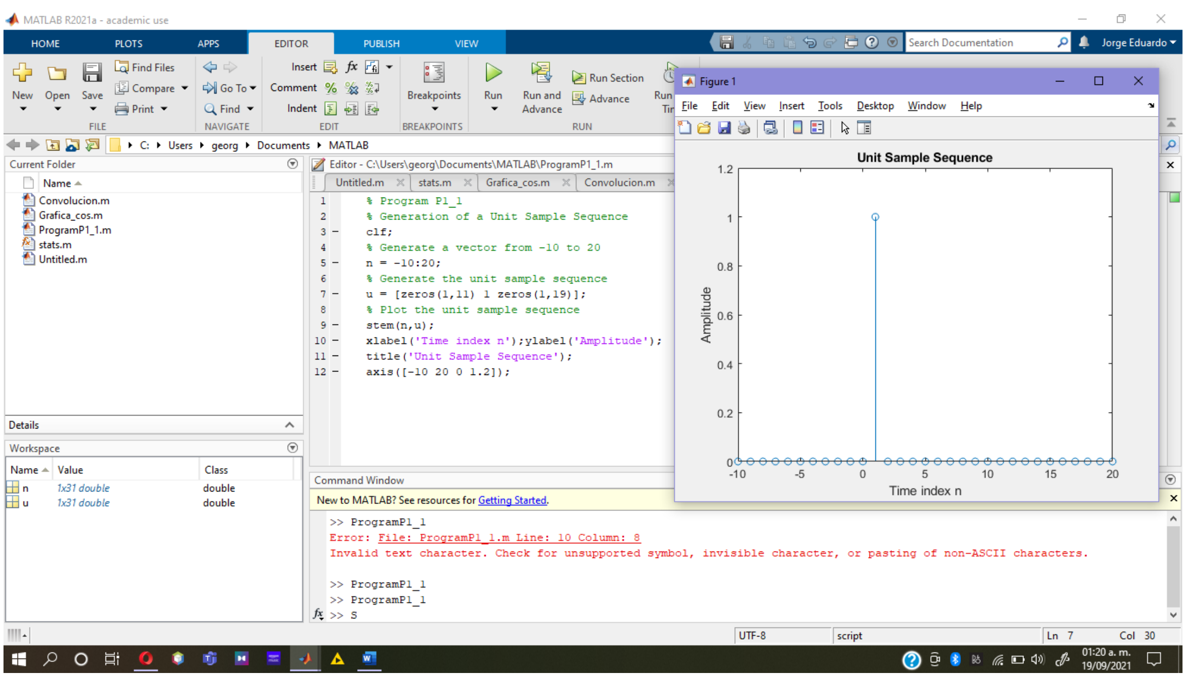
Title sirve para añadir un título al gráfico generado.

Xlabel añade un título al eje X.

Ylabel añade un título al eje Y

3) Q1.3 Modify Program P1 1 to generate a delayed unit sample sequence ud[n] with a delay of 11 samples. Run the modified program and display the sequence generated.

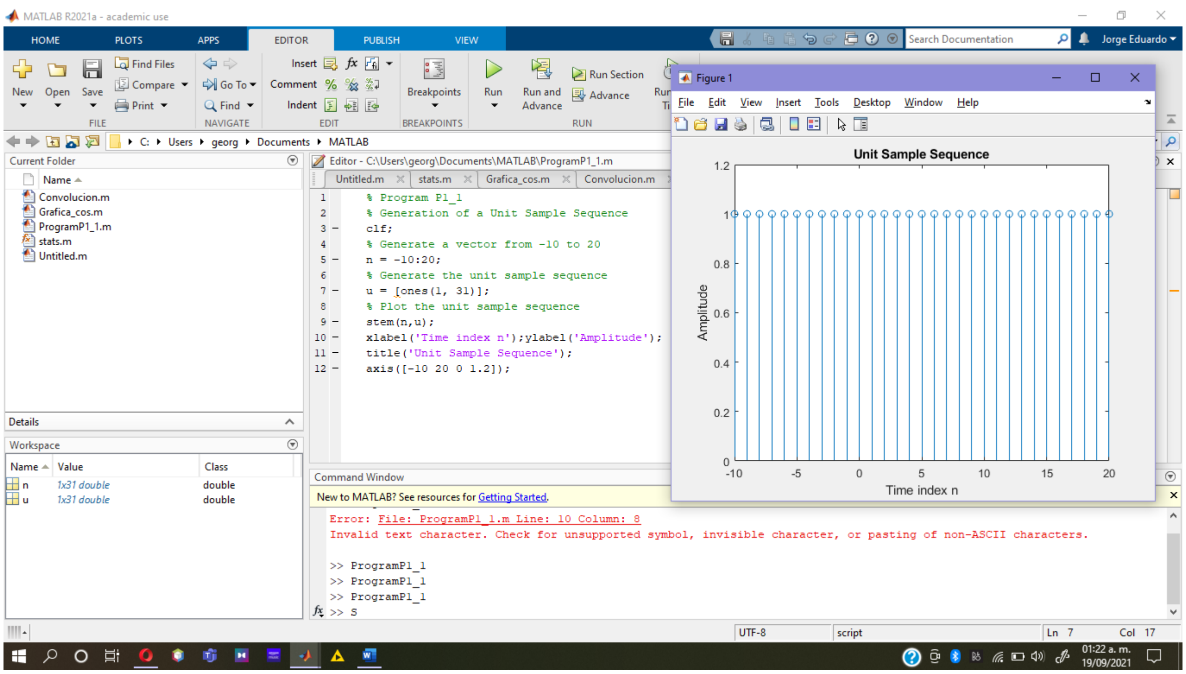
```
% Program P1_1
% Generation of a Unit Sample Sequence
clf;
% Generate a vector from -10 to 20
n = -10:20;
% Generate the unit sample sequence
u = [zeros(1,11) 1 zeros(1,19)];
% Plot the unit sample sequence
stem(n,u);
      xlabel('Time index n');ylabel('Amplitude');
      title('Unit Sample Sequence');
      axis([-10 20 0 1.2]);
```




4) Q1.4 Modify Program P1 1 to generate a unit step sequence s[n]. Run the modified program and display the sequence generated.

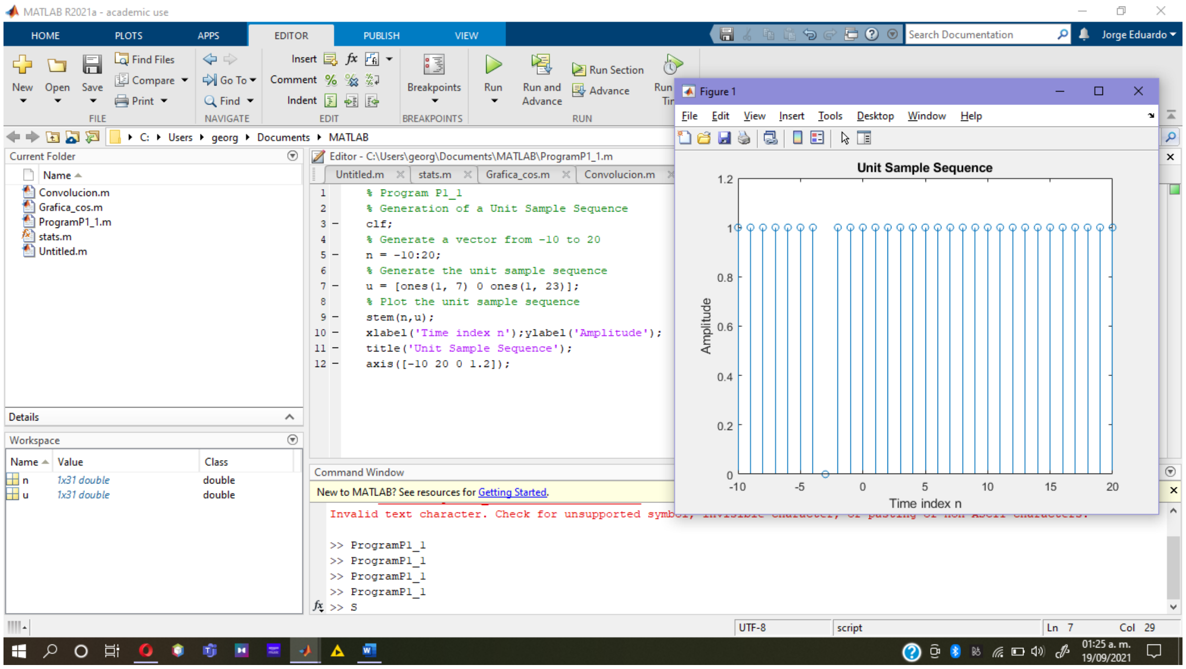
```
% Program P1_1
% Generation of a Unit Sample Sequence
```

```
clf;
% Generate a vector from -10 to 20
n = -10:20;
% Generate the unit sample sequence
u = [ones(1, 31)];
% Plot the unit sample sequence
stem(n,u);
xlabel('Time index n');ylabel('Amplitude');
title('Unit Sample Sequence');
axis([-10 20 0 1.2]);
```




5) Q1.5 Modify Program P1 1 to generate a delayed unit step sequence sd[n] with an advance of 7 samples. Run the modified program and display the sequence generated.

```
% Program P1_1
% Generation of a Unit Sample Sequence
clf;
% Generate a vector from -10 to 20
n = -10:20;
% Generate the unit sample sequence
u = [ones(1, 7) 0 ones(1, 23)];
% Plot the unit sample sequence
stem(n,u);
xlabel('Time index n');ylabel('Amplitude');
title('Unit Sample Sequence');
axis([-10 20 0 1.2]);
```


MATLAB R2021a - academic use
HOME
PLOTS
APPS
EDITOR
PUBLISH
VIEW
Search Documentation
Jorge Eduardo
Current Folder
Name
Convolucion.m
Grafica_cos.m
ProgramP1_1.m
stats.m
Untitled.m
Details
Workspace
Name
Value
Class
n
1x31 double
double
u
1x31 double
double
Editor - C:\Users\georg\Documents\MATLAB\ProgramP1_1.m
Untitled.m
stats.m
Grafica_cos.m
Convolucion.m
% Program P1_1
% Generation of a Unit Sample Sequence
clf;
% Generate a vector from -10 to 20
n = -10:20;
% Generate the unit sample sequence
u = [ones(1, 7) 0 ones(1, 23)];
% Plot the unit sample sequence
stem(n,u);
xlabel('Time index n');ylabel('Amplitude');
title('Unit Sample Sequence');
axis([-10 20 0 1.2]);
Command Window
New to MATLAB? See resources for Getting Started.
Invalid text character. Check for unsupported symbol, invisible character, or pasting of non-ASCII characters.
>> ProgramP1_1
>> ProgramP1_1
>> ProgramP1_1
>> ProgramP1_1
>> s
Figure 1
File Edit View Insert Tools Desktop Window Help
Unit Sample Sequence
Amplitude
Time index n
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script
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## B. Project 1.2 Exponential Signals

Program P1 2 given below can be employed to generate a complex-valued exponential sequence.

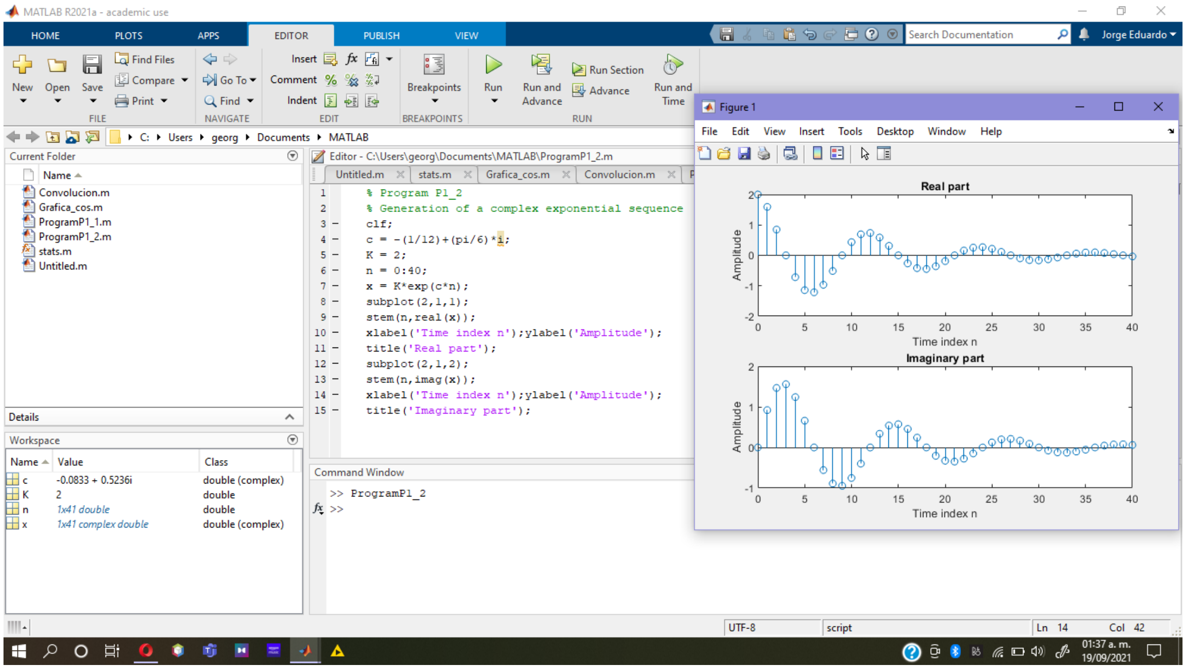
```
% Program P1_2
% Generation of a complex exponential sequence
clf;
c = -(1/12)+(pi/6)*i;
K = 2;
n = 0:40;
x = K*exp(c*n);
subplot(2,1,1);
stem(n,real(x));
xlabel('Time index n');ylabel('Amplitude');
title('Real part');
subplot(2,1,2);
stem(n,imag(x));
xlabel('Time index n');ylabel('Amplitude');
title('Imaginary part');
```

Program P1 3 given below can be employed to generate a real-valued exponential sequence.

```
% Program P1_3
% Generation of a real exponential sequence
clf;
n = 0:35; a = 1.2; K = 0.2;
x = K*a.^+n;
stem(n,x);
xlabel('Time index n');ylabel('Amplitude');
```

- **Questions:**

6) Q1.6 Run Program P1 2 and generate the complex-valued exponential sequence.

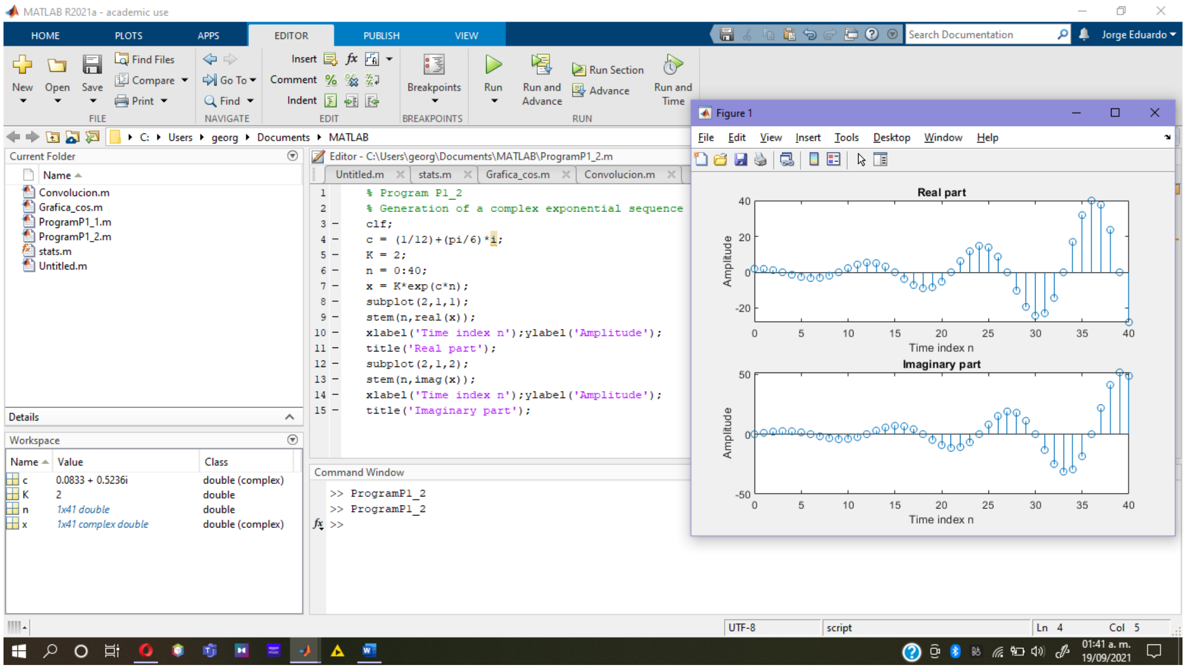



7) Q1.7 Which parameter controls the rate of growth or decay of this sequence? Which parameter controls the amplitude of this sequence?

El rango N controla la frecuencia con la que aparecen valores en la gráfica. Mientras más se extiende el rango, más valores aparecen. K controla la amplitud con la que los valores crecen o decrecen en la gráfica.

8) Q1.8 What will happen if the parameter c is changed to (1/12)+(pi/6)*i?

La gráfica se invierte tomando como referencia el eje Y, es decir, los valores inician con poca amplitud, y conforme se recorre la gráfica hacia la derecha, hacia mayores valores de X, la amplitud aumenta.



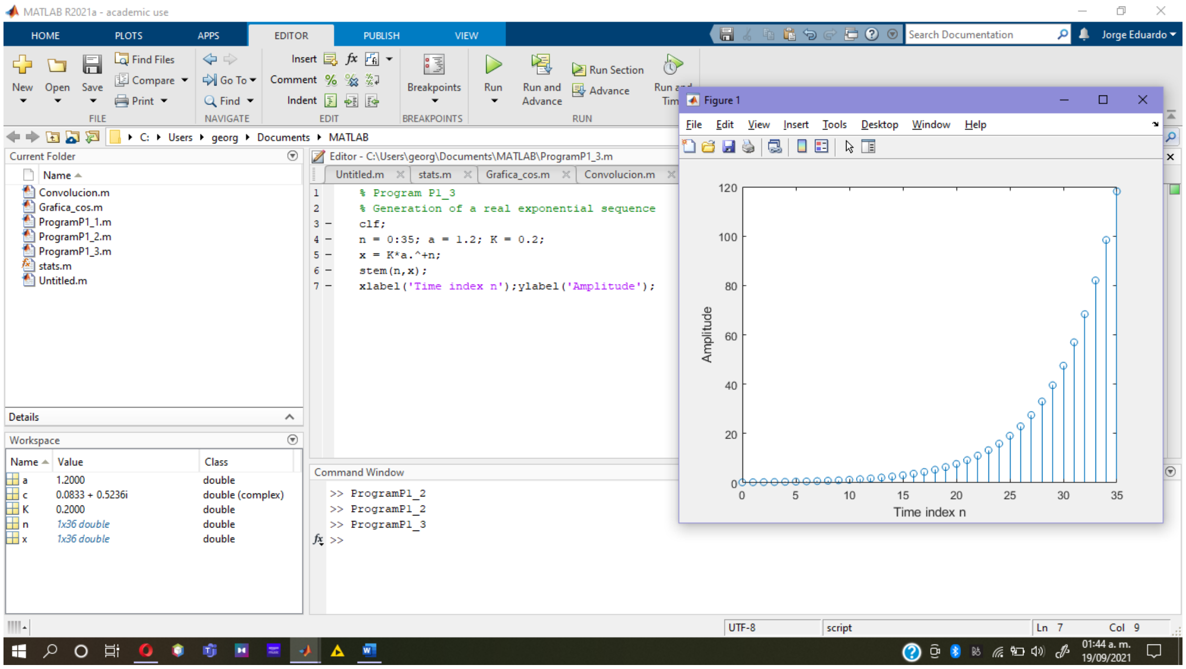
9) Q1.9 What are the purposes of the operators real and imag?

Los operadores diferencian cuando hay una parte real o imaginaria de una expresión. Esto se aprecia en la gráfica que genera el programa. Entre la parte real y la imaginaria, hay un ligero desfase, además de que la amplitud entre los valores de cada gráfica también varía.

10) Q1.10 What is the purpose of the command subplot?

El comando divide la ventana Figure en diferentes secciones, permitiendo mostrar dos gráficas en la misma ventana. Podemos ver que los valores cambian de subplot(2,1,1) a subplot(2,1,2), esto nos indica que el primer conjunto de valores corresponde a la gráfica que se mostrará en la parte superior, y el segundo conjunto a la gráfica que se mostrará en la parte inferior de la ventana Figure.

11) Q1.11 Run Program P1 3 and generate the real-valued exponential sequence.



12) Q1.12 Which parameter controls the rate of growth or decay of this sequence? Which parameter controls the amplitude of this sequence?

La variable K define la tasa con la que crece la gráfica en general.

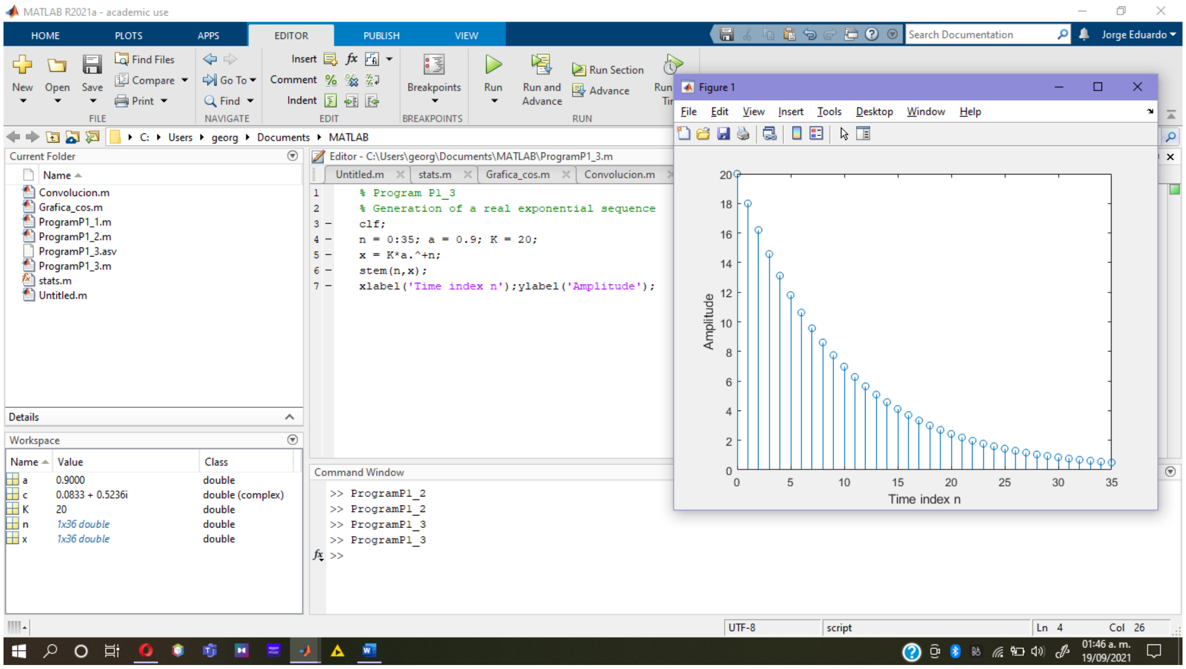
La variable A define la amplitud de cada valor de la secuencia.

13) Q1.13 What is the difference between the arithmetic operators ^ and .^?

El operador ^ es una potencia de matrices, mientras que el operador .^ es una potencia de arreglos. Para dar un ejemplo del caso, si quisiéramos resolver la operación Z = X .^ Y, obtendríamos un error si X y Y fueran matrices, por lo tanto, para obtener un resultado válido, deberíamos realizar la operación Z= X ^ Y, donde Y debería ser un escalar y X una matriz cuadrada.

14) Q1.14 What will happen if the parameter a is less than 1? Run Program P1 3 again with the parameter a changed to 0.9 and the parameter K changed to 20.

Cuando los valores cambian tal y como dice el inciso, la orientación de la gráfica cambia. Inicia con valores grandes y decrece exponencialmente.

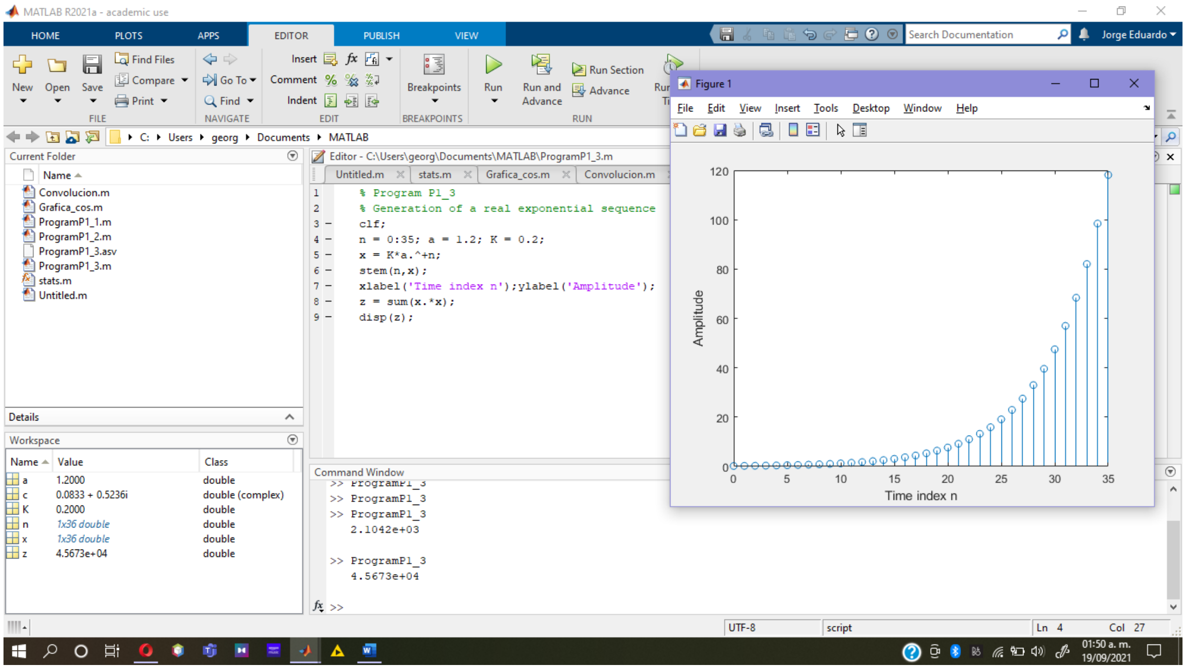


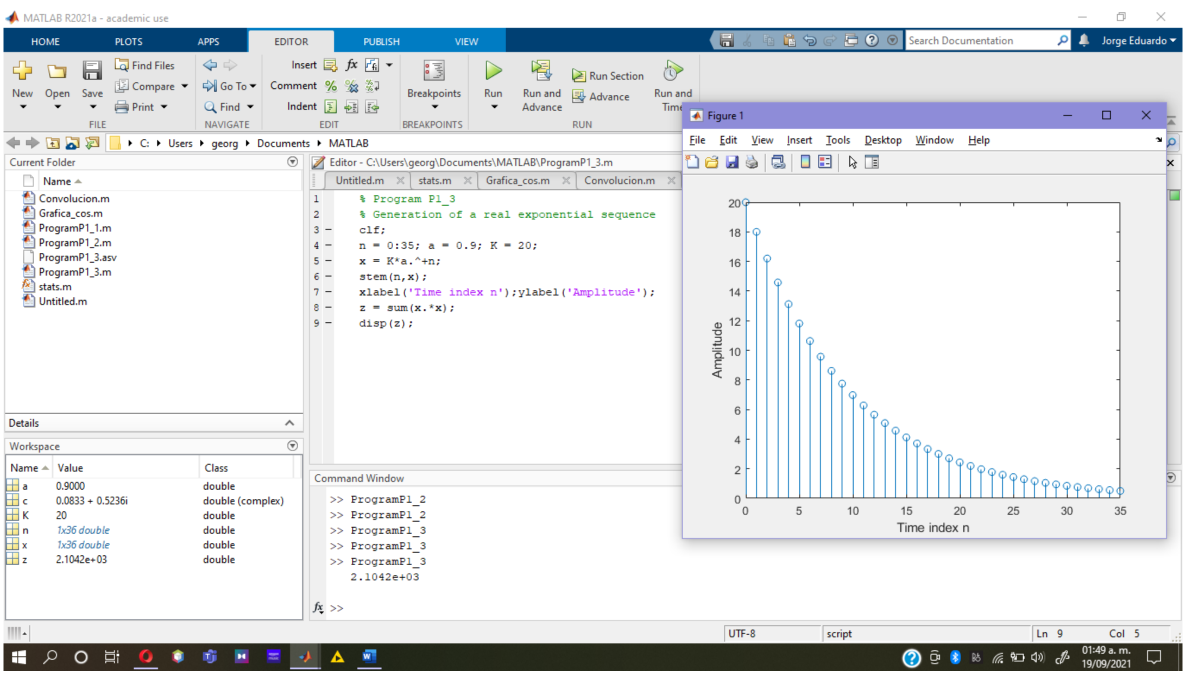

15) Q1.15 What is the length of this sequence and how can it be changed?

La gráfica se muestra para 35 valores de X con los valores que da el programa al inicio. Para aumentar o disminuir el rango en X, hay que ampliar o disminuir el valor de la variable n.

16) Q1.16 You can use the MATLAB command sum(s.*s) to compute the energy of a real sequence s[n] stored as a vector s. Evaluate the energy of the real-valued exponential sequences x[n] generated in Questions Q1.11 and Q1.14.

Si comparamos los valores de ambos casos, vemos que el valor de la energía del segundo caso es menor que el del primero


MATLAB R2021a - academic use
Editor - C:\Users\georg\Documents\MATLAB\ProgramP1_3.m
% Program P1_3
% Generation of a real exponential sequence
clf;
n = 0:35; a = 1.2; K = 0.2;
x = K*a.^+n;
stem(n,x);
xlabel('Time index n');ylabel('Amplitude');
z = sum(x.*x);
disp(z);
Command Window
>> ProgramP1_3
>> ProgramP1_3
2.1042e+03
>> ProgramP1_3
4.5673e+04
Workspace
a 1.2000 double
c 0.0833 + 0.5236i double (complex)
K 0.2000 double
n 1x36 double double
x 1x36 double double
z 4.5673e+04 double
Figure 1
Amplitude
Time index n


MATLAB R2021a - academic use
Editor - C:\Users\georg\Documents\MATLAB\ProgramP1_3.m
% Program P1_3
% Generation of a real exponential sequence
clf;
n = 0:35; a = 0.9; K = 20;
x = K*a.^+n;
stem(n,x);
xlabel('Time index n');ylabel('Amplitude');
z = sum(x.*x);
disp(z);
Command Window
>> ProgramP1_2
>> ProgramP1_2
>> ProgramP1_3
>> ProgramP1_3
>> ProgramP1_3
2.1042e+03
Workspace
a 0.9000 double
c 0.0833 + 0.5236i double (complex)
K 20 double
n 1x36 double double
x 1x36 double double
z 2.1042e+03 double
Figure 1
Amplitude
Time index n

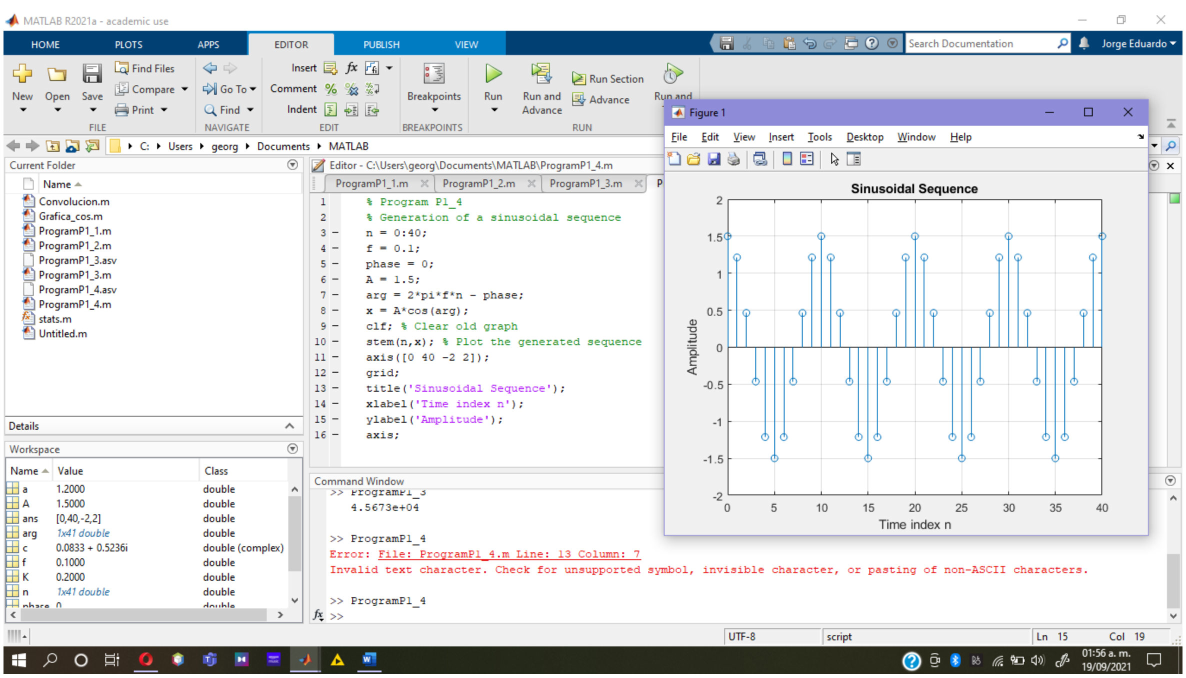
# C. Project 1.3 Sinusoidal Sequences

Program P1 4 is a simple example that generates a sinusoidal signal.

```
% Program P1_4
% Generation of a sinusoidal sequence
n = 0:40;
f = 0.1;
phase = 0;
A = 1.5;
arg = 2*pi*f*n – phase;
x = A*cos(arg);
clf; % Clear old graph
        stem(n,x); % Plot the generated sequence
        axis([0 40 -2 2]);
        grid;
        title('Sinusoidal Sequence');
        xlabel('Time index n');
        ylabel('Amplitude');
        axis;
```

- **Questions:**

17) Q1.17 Run Program P1 4 to generate the sinusoidal sequence and display it.



18) Q1.18 What is the frequency of this sequence and how can it be changed? Which parameter controls the phase of this sequence? Which parameter controls the amplitude of this sequence? What is the period of this sequence?

La frecuencia es de 0.1 y le corresponde la variable f.

La fase corresponde a la variable “phase”.

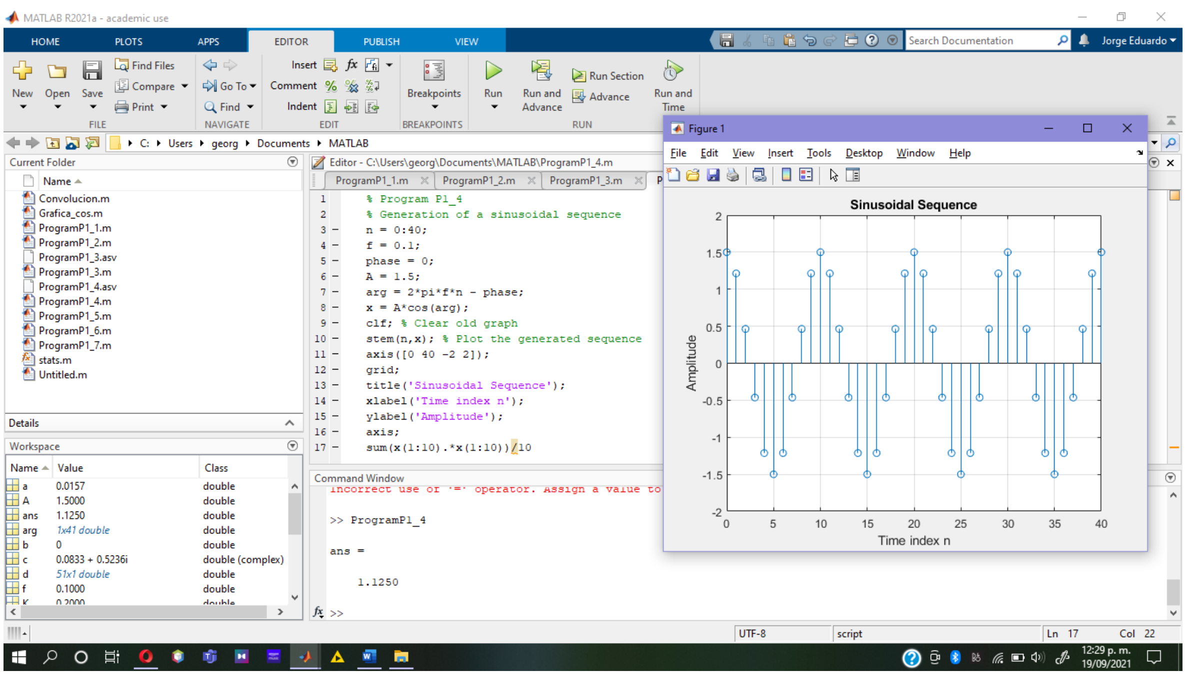
El parámetro de la amplitud es la variable A.

El periodo es de 10, y se calcula con la fórmula $T = \frac{1}{f}$

19) Q1.19 What is the length of this sequence and how can it be changed?

La longitud de la secuencia depende del intervalo n. Se puede cambiar al aumentar o disminuir el tamaño del intervalo.

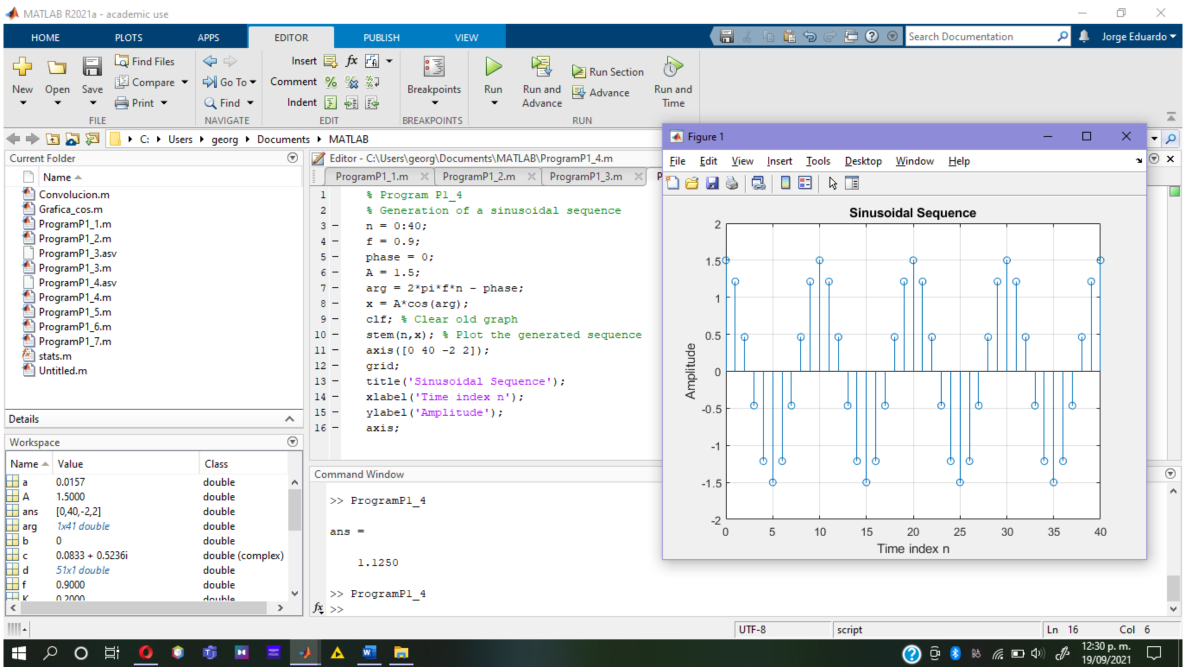
20) Q1.20 Compute the average power of the generated sinusoidal sequence.




21) Q1.21 What are the purposes of the axis and grid commands?

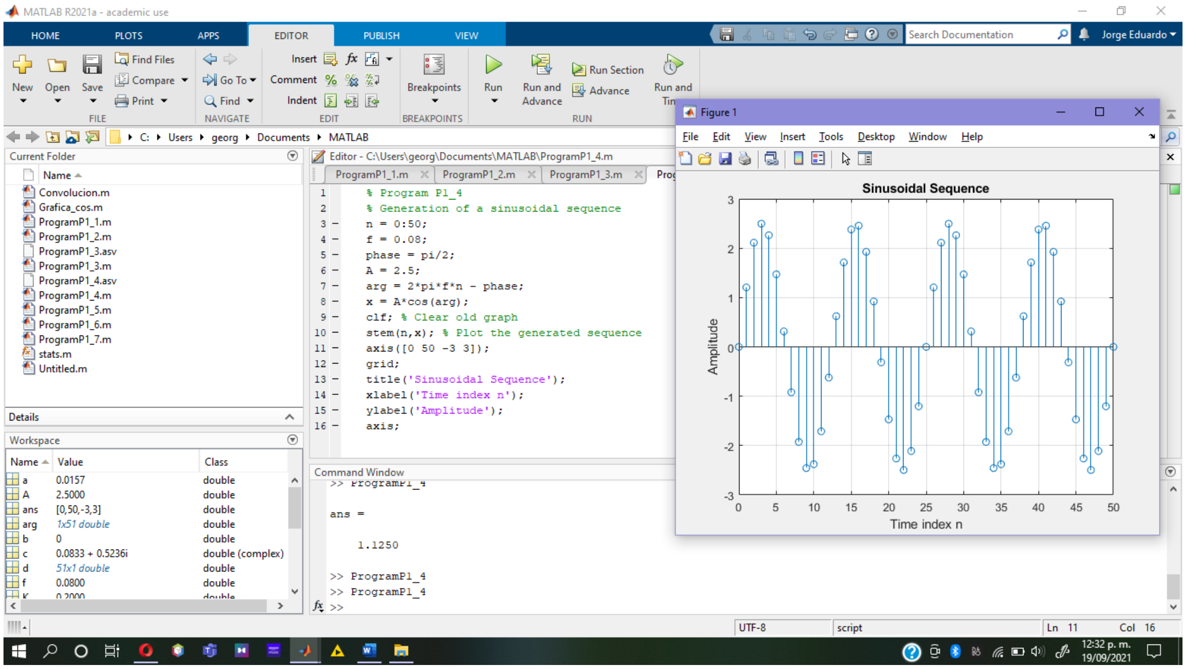
El comando axis especifica los límites de los ejes. El comando grid muestra una cuadrícula dentro de la figura

22) Q1.22 Modify Program P1 4 to generate a sinusoidal sequence of frequency 0.9 and display it. Compare this new sequence with the one generated in Question Q1.17. Now, modify Program P1 4 to generate a sinusoidal sequence of frequency 1.1 and display it. Compare this new sequence with the one generated in Question Q1.17. Comment on your results.



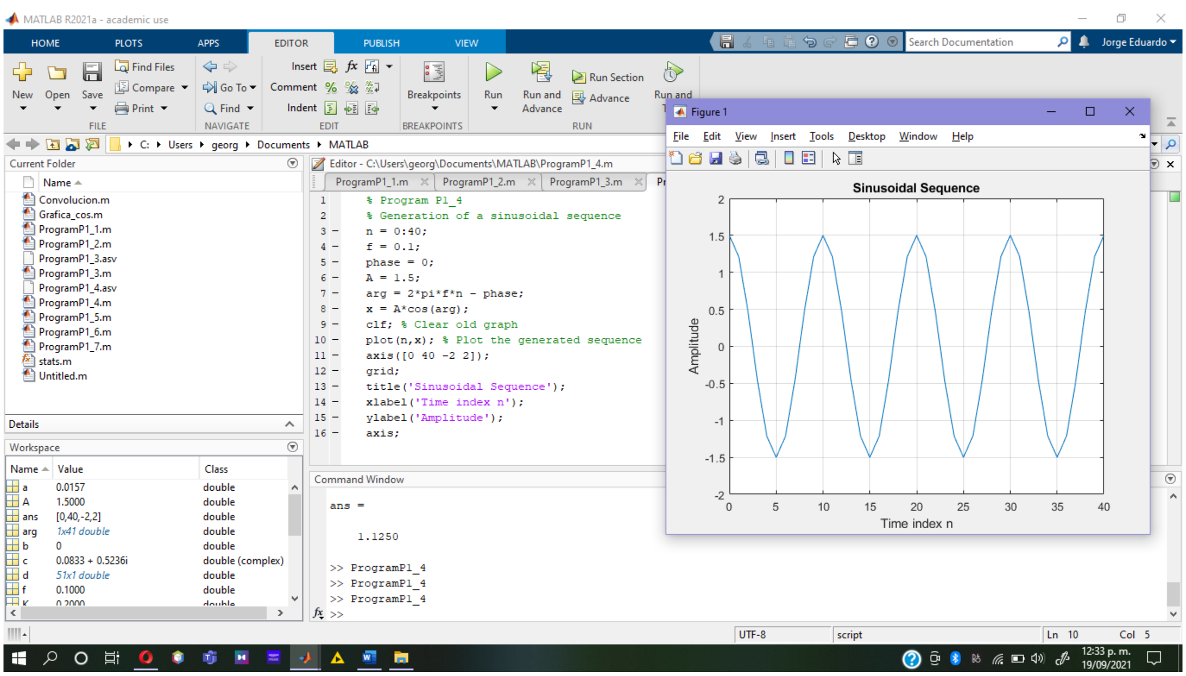

23) Q1.23 Modify the above program to generate a sinusoidal sequence of length 50, frequency 0.08, amplitude 2.5, and phase shift 90 degrees and display it. What is the period of this sequence?

El periodo de la secuencia se calcula con la fórmula: $T = \frac{1}{f} = \frac{1}{0.08} = 12.5$



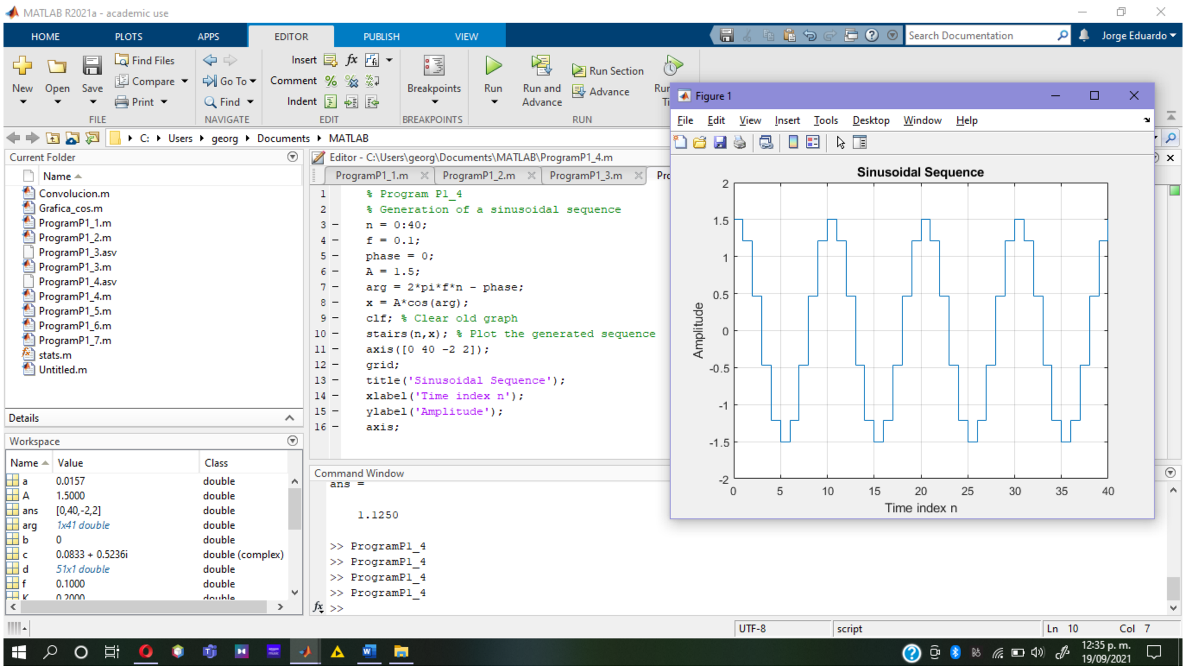
24) Q1.24 Replace the stem command in Program P1 4 with the plot command and run the program again. What is the difference between the new plot and the one generated in Question Q1.17?

Lo que se modifica en la figura es la definición de la gráfica, lo que la vuelve más continua y curva a simple vista.



25) Q1.25 Replace the stem command in Program P1 4 with the stairs command and run the program again. What is the difference between the new plot and those generated in Questions Q1.17 and Q1.24?

La gráfica se vuelve cuadrada como lo indica el comando, “stairs” en español significa escalera.

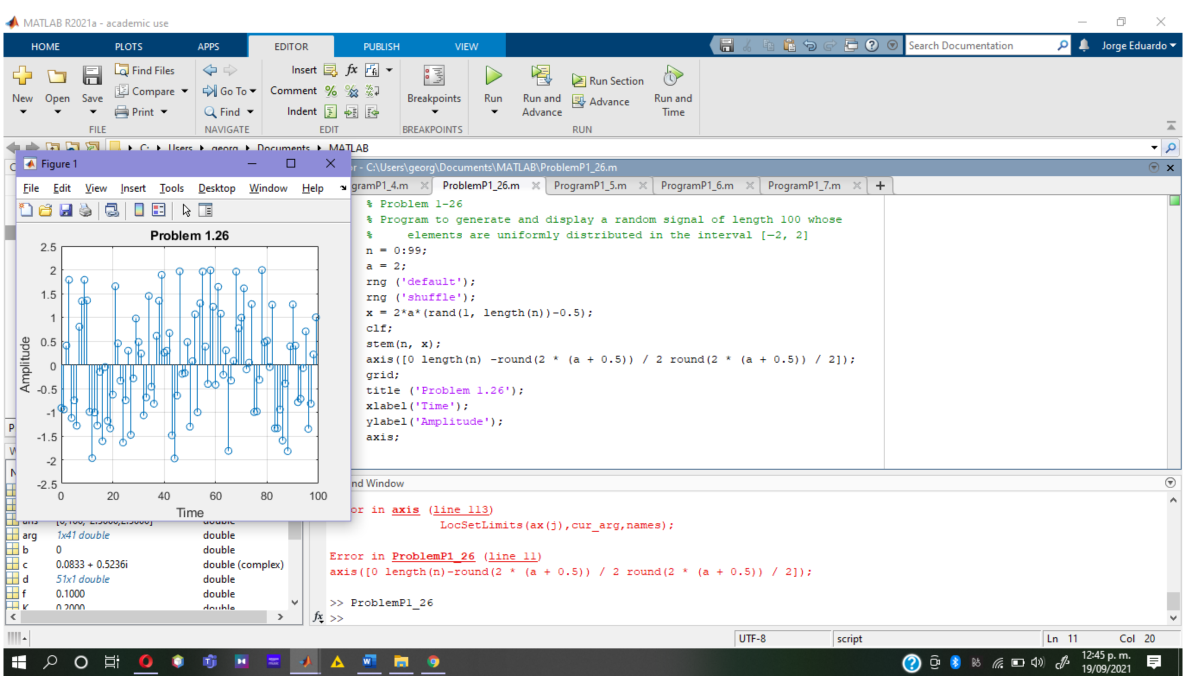


## D. Project 1.4 Random Signals

- **Questions:**

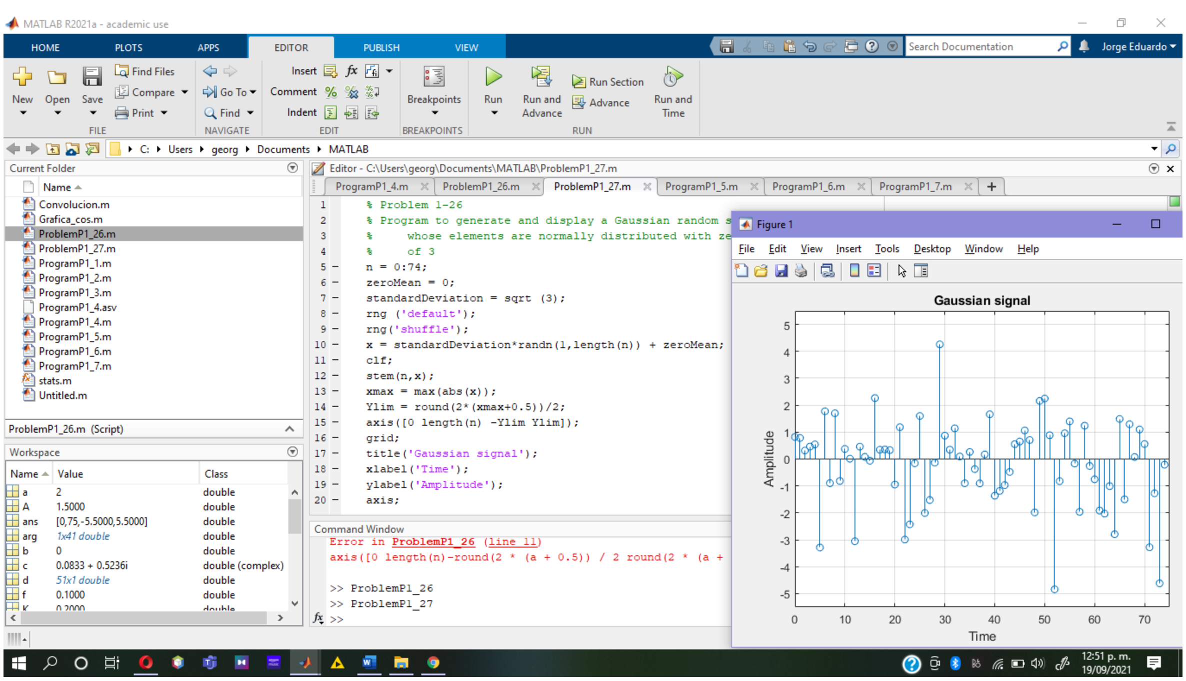
26) Q1.26 Write a MATLAB program to generate and display a random signal of length 100 whose elements are uniformly distributed in the interval [−2, 2].

```
% Problem 1-26
% Program to generate and display a random signal of length 100 whose
%      elements are uniformly distributed in the interval [-2, 2]
n = 0:99;
a = 2;
rng ('default');
rng ('shuffle');
x = 2*a*(rand(1, length(n))-0.5);
clf;
     stem(n, x);
     axis([0 length(n) -round(2 * (a + 0.5)) / 2 round(2 * (a + 0.5)) / 2]);
     grid;
     title ('Problem 1.26');
     xlabel('Time');
     ylabel('Amplitude');
     axis;
```



27) Q1.27 Write a MATLAB program to generate and display a Gaussian random signal of length 75 whose elements are normally distributed with zero mean and a variance of 3.

```
% Problem 1-27
% Program to generate and display a Gaussian random signal of length 75
%       whose elements are normally distributed with zero mean and a variance
%       of 3
n = 0:74;
zeroMean = 0;
standardDeviation = sqrt (3);
rng ('default');
rng('shuffle');
        x = standardDeviation*randn(1,length(n)) + zeroMean;
        clf;
        stem(n,x);
        xmax = max(abs(x));
        Ylim = round(2*(xmax+0.5))/2;
        axis([0 length(n) -Ylim Ylim]);
        grid;
        title('Gaussian signal');
        xlabel('Time');
        ylabel('Amplitude');
        axis;
```

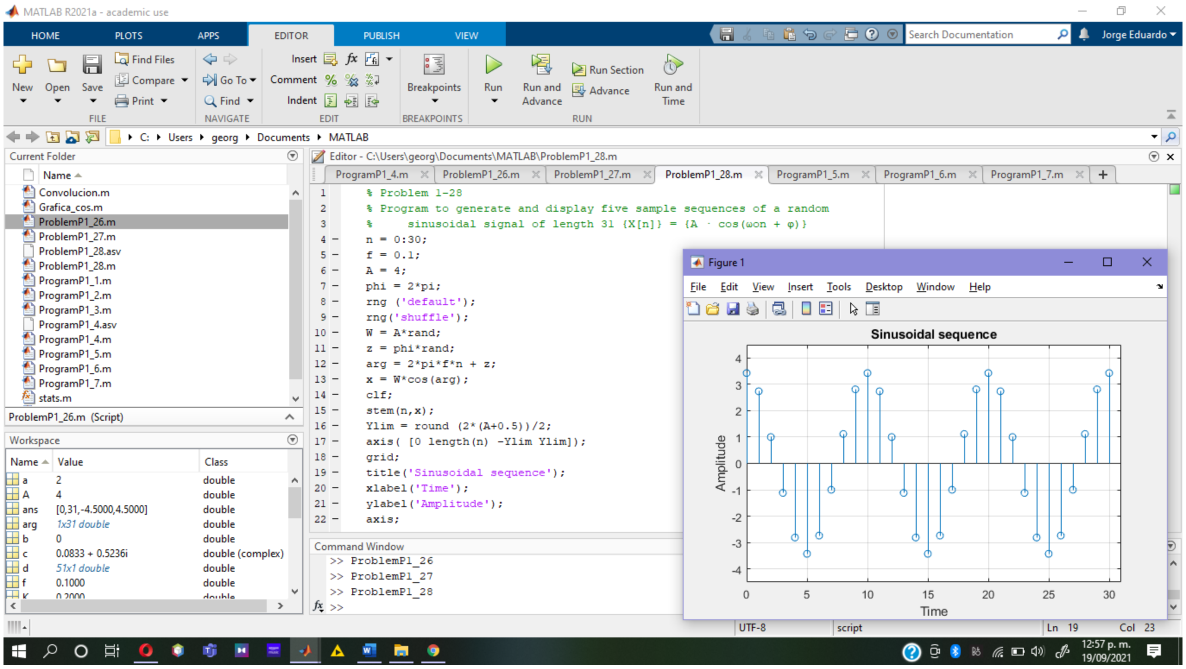


28) Q1.28 Write a MATLAB program to generate and display five sample sequences of a random sinusoidal signal of length 31

$$X[n] = A \cdot cos(\omega o n + \phi),$$

where the amplitude A and the phase φ are statistically independent random variables with uniform probability distribution in the range $0 \leq A \leq 4$ for the amplitude and in the range $0 \leq \phi \leq 2\pi$ for the phase.

```
% Problem 1-28
% Program to generate and display five sample sequences of a random
%     sinusoidal signal of length 31 {X[n]} = {A · cos(ωon + φ)}
n = 0:30;
f = 0.1;
A = 4;
phi = 2*pi;
rng ('default');
rng('shuffle');
        W = A*rand;
        z = phi*rand;
        arg = 2*pi*f*n + z;
        x = W*cos(arg);
        clf;
        stem(n,x);
        Ylim = round (2*(A+0.5))/2;
        axis( [0 length(n) -Ylim Ylim]);
        grid;
        title('Sinusoidal sequence');
        xlabel('Time');
        ylabel('Amplitude');
        axis;
```


MATLAB R2021a - academic use
Editor - C:\Users\georg\Documents\MATLAB\ProblemP1_28.m
% Problem 1-28
% Program to generate and display five sample sequences of a random
% sinusoidal signal of length 31 {X[n]} = {A · cos(ωon + φ)}
n = 0:30;
f = 0.1;
A = 4;
phi = 2*pi;
rng ('default');
rng('shuffle');
W = A*rand;
z = phi*rand;
arg = 2*pi*f*n + z;
x = W*cos(arg);
clf;
stem(n,x);
Ylim = round (2*(A+0.5))/2;
axis( [0 length(n) -Ylim Ylim]);
grid;
title('Sinusoidal sequence');
xlabel('Time');
ylabel('Amplitude');
axis;
Command Window
>> ProblemP1_26
>> ProblemP1_27
>> ProblemP1_28
Figure 1
Sinusoidal sequence
Amplitude
Time

## E. Project 1.5 Signal Smoothing

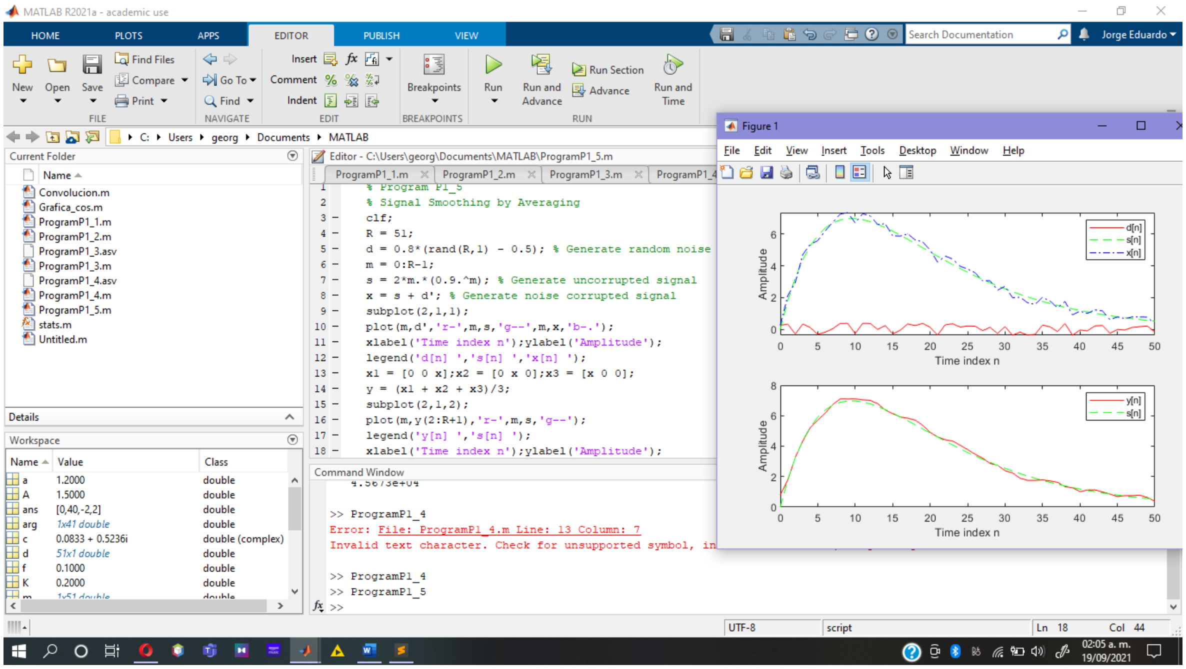
$$y[n] = \frac{1}{3}(x[n-1] + x[n] + x[n+1]),$$

Program P1 5 implements the above algorithm.

```
% Program P1_5
% Signal Smoothing by Averaging
clf;
R = 51;
d = 0.8*(rand(R,1) - 0.5); % Generate random noise
m = 0:R-1;
s = 2*m.*(0.9.^m); % Generate uncorrupted signal
x = s + d'; % Generate noise corrupted signal
subplot(2,1,1);
    plot(m,d','r-',m,s,'g--',m,x,'b-.');
    xlabel('Time index n');ylabel('Amplitude');
    legend('d[n] ','s[n] ','x[n] ');
    x1 = [0 0 x];x2 = [0 x 0];x3 = [x 0 0];
    y = (x1 + x2 + x3)/3;
    subplot(2,1,2);
    plot(m,y(2:R+1),'r-',m,s,'g--');
    legend('y[n] ','s[n] ');
    xlabel('Time index n');ylabel('Amplitude');
```

- **Questions:**

29) Q1.29 Run Program P1 5 and generate all pertinent signals.




30) Q1.30 What is the form of the uncorrupted signal s[n]? What is the form of the additive noise d[n]?

La señal incorrupta se obtiene de un crecimiento lineal con una caída exponencial. El ruido aditivo se obtiene de una secuencia distribuida entre -0.4 y 0.4.

31) Q1.31 Can you use the statement x=s+d to generate the noise-corrupted signal? If not, why not?

No es posible porque un vector está en forma de columna y otro en forma de fila, por lo que no podría generarse tal como están.

32) Q1.32 What are the relations between the signals x1, x2, and x3, and the signal x?

Las señales X1, X2 y X3 son extensiones de la señal X. La señal X1 se encuentra retrasada. La señal X2 es igual a la señal X y la señal X3 se encuentra adelantada por cierto tiempo de la señal X

33) Q1.33 What is the purpose of the legend command?

El comando legend crea un identificador para las diferentes gráficas de la figura.

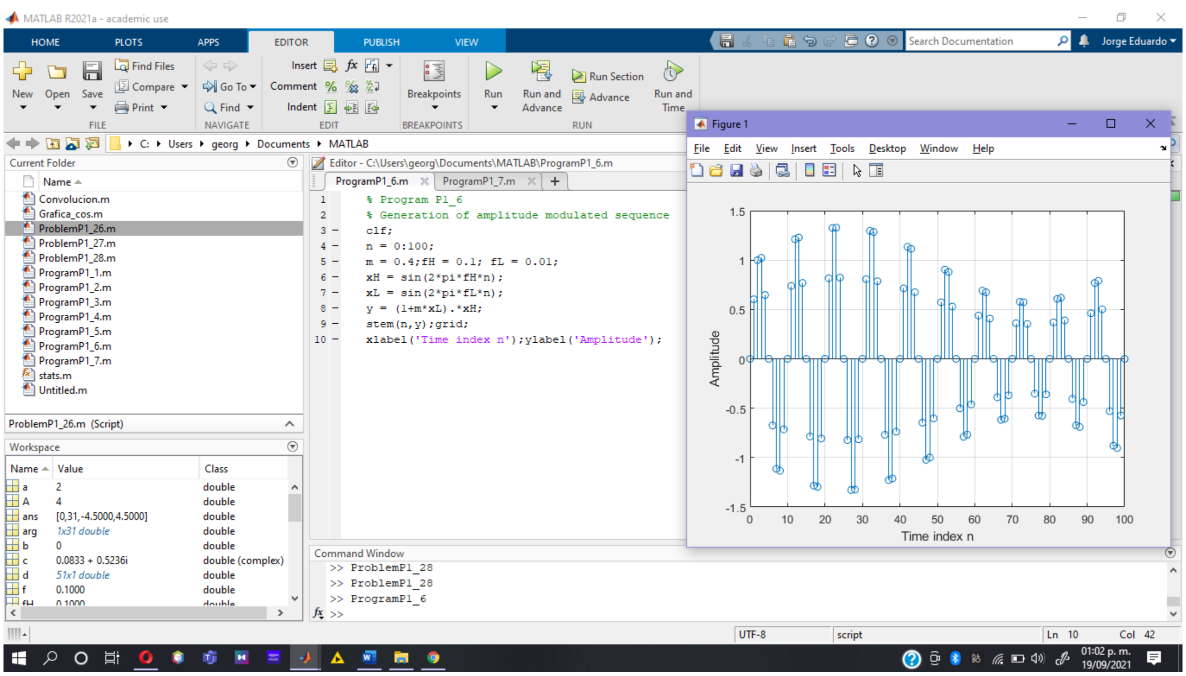
## F. Project 1.6 Generation of Complex Signals

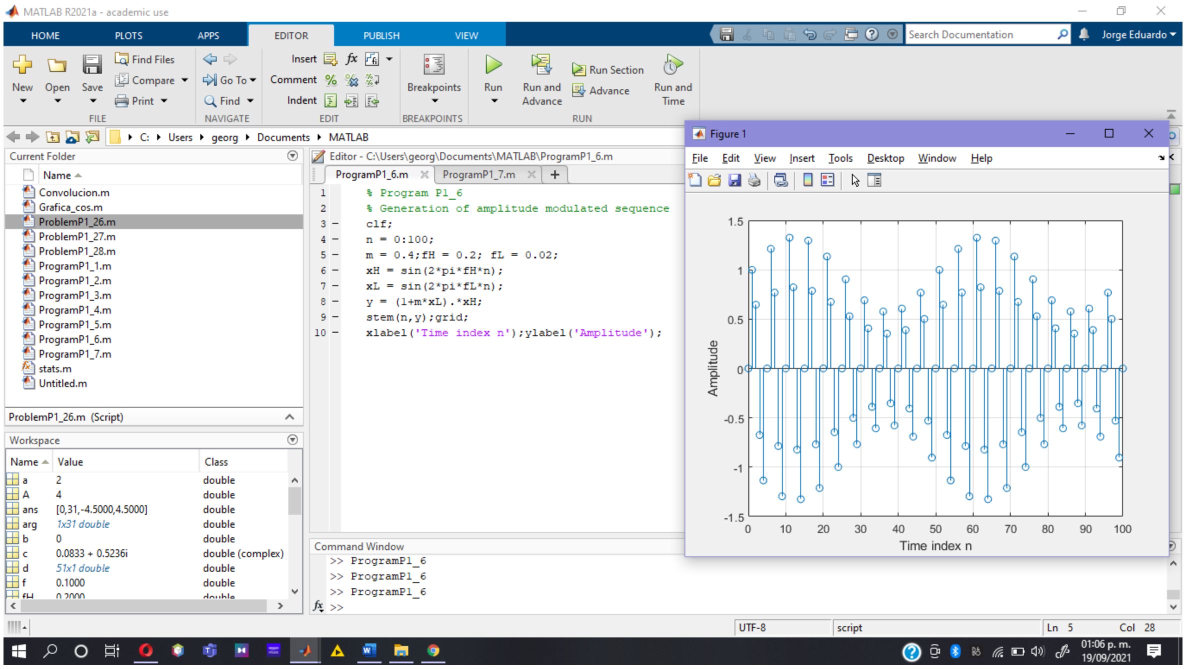
Program P1 6 can be used to generate an amplitude modulated signal.

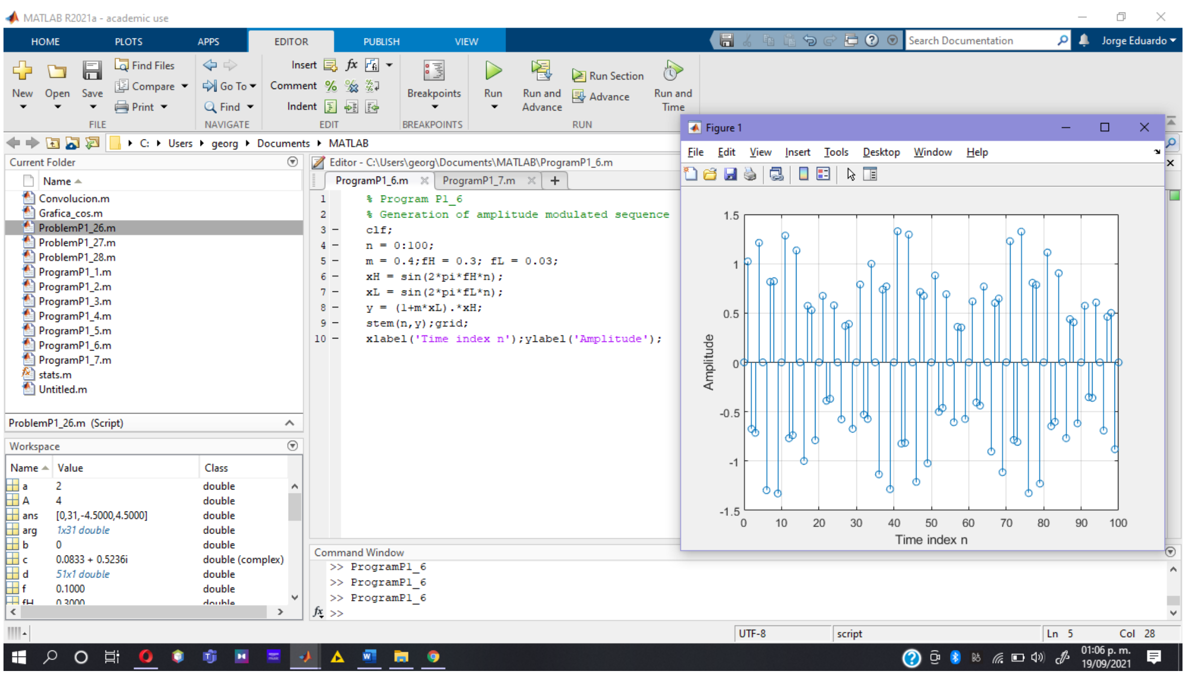
```
% Program P1_6
% Generation of amplitude modulated sequence
clf;
n = 0:100;
m = 0.4;fH = 0.1; fL = 0.01;
xH = sin(2*pi*fH*n);
xL = sin(2*pi*fL*n);
y = (1+m*xL).*xH;
stem(n,y);grid;
        xlabel('Time index n');ylabel('Amplitude');
```

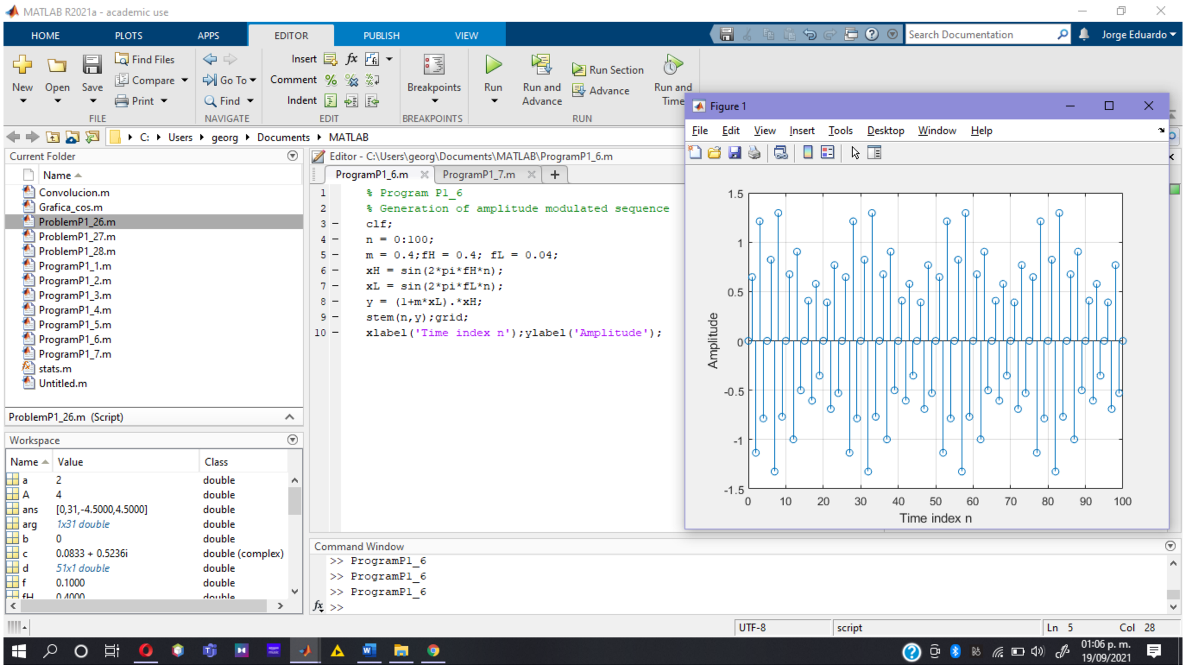
- **Questions:**

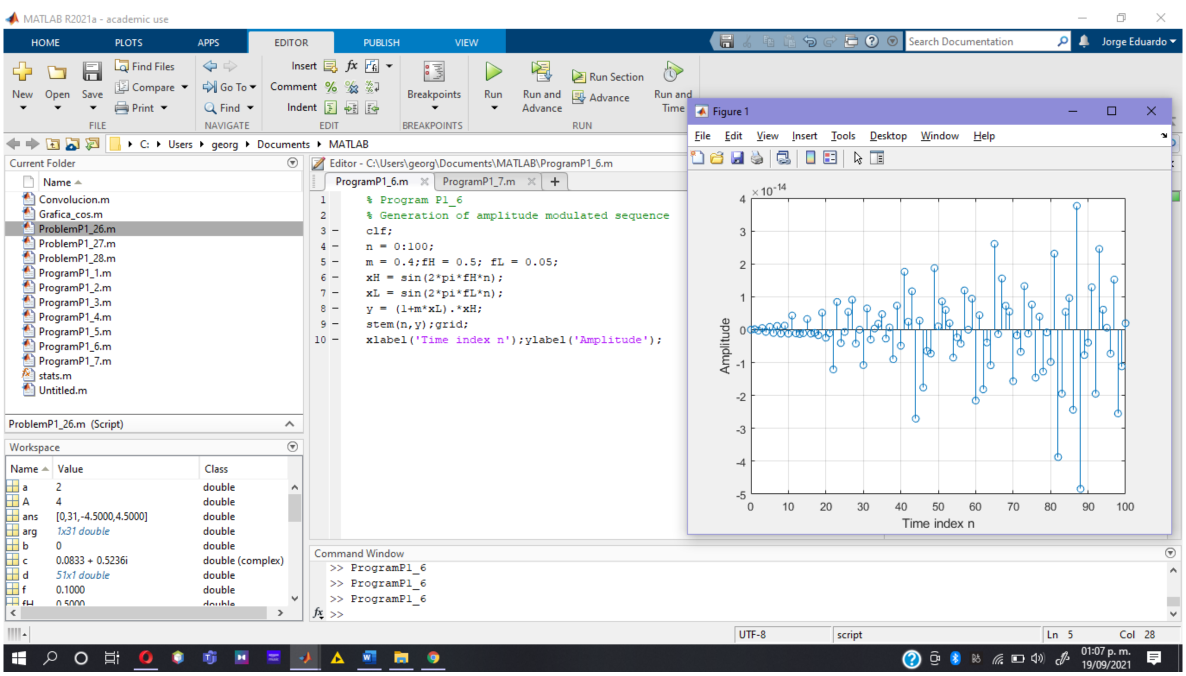
34) Q1.34 Run Program P1 6 and generate the amplitude modulated signal y[n] for various values of the frequencies of the carrier signal xH[n] and the modulating signal xL[n], and various values of the modulation index m.




MATLAB R2021a - academic use
Editor - C:\Users\georg\Documents\MATLAB\ProgramP1_6.m
% Program P1_6
% Generation of amplitude modulated sequence
clf;
n = 0:100;
m = 0.4;fH = 0.2; fL = 0.02;
xH = sin(2*pi*fH*n);
xL = sin(2*pi*fL*n);
y = (1+m*xL).*xH;
stem(n,y);grid;
xlabel('Time index n');ylabel('Amplitude');
Figure 1
Amplitude
Time index n
Command Window
>> ProgramP1_6
>> ProgramP1_6
>> ProgramP1_6


MATLAB R2021a - academic use
Editor - C:\Users\georg\Documents\MATLAB\ProgramP1_6.m
% Program P1_6
% Generation of amplitude modulated sequence
clf;
n = 0:100;
m = 0.4;fH = 0.3; fL = 0.03;
xH = sin(2*pi*fH*n);
xL = sin(2*pi*fL*n);
y = (1+m*xL).*xH;
stem(n,y);grid;
xlabel('Time index n');ylabel('Amplitude');
Figure 1
Amplitude
Time index n
Command Window
>> ProgramP1_6
>> ProgramP1_6
>> ProgramP1_6




35) Q1.35 What is the difference between the arithmetic operators * and .* ?

El operador * multiplica dos matrices de vectores usando producto de matrices.

El operador .* calcula el producto escalar entre dos vectores.

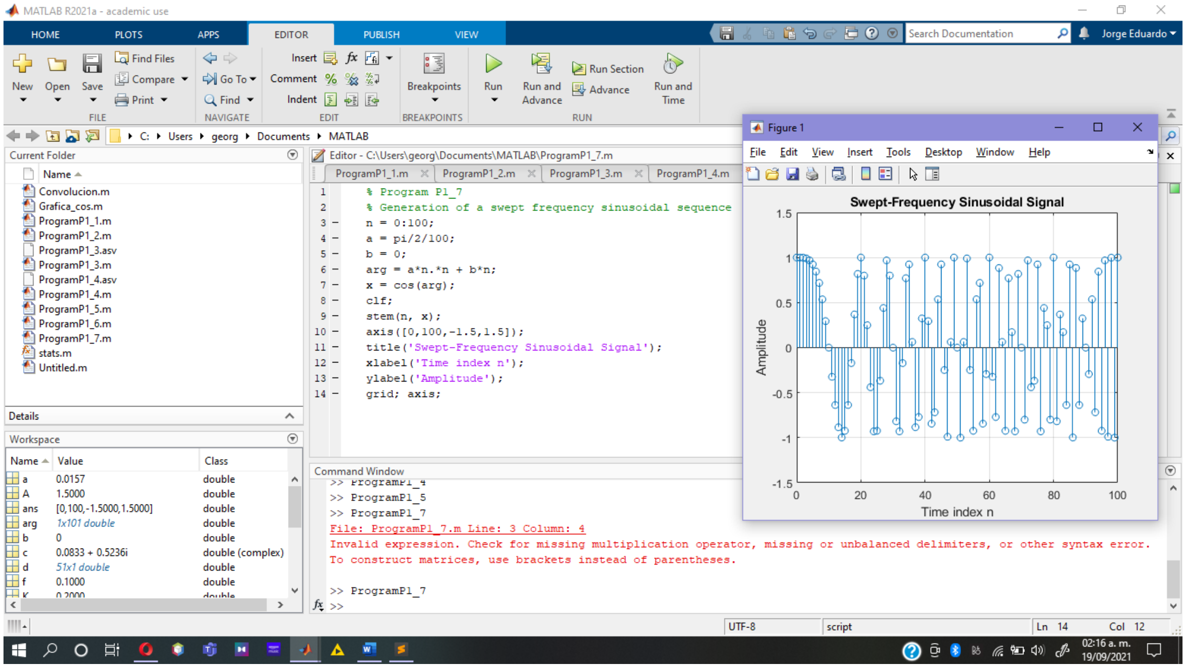
As the frequency of a sinusoidal signal is the derivative of its phase with respect to time, to generate a swept-frequency sinusoidal signal whose frequency increases linearly with time, the argument of the sinusoidal signal must be a quadratic function of time. Assume that the argument is of the form $an^2 + bn$ (i.e. the angular frequency is $2an + b$). Solve for the values of a and b from the given conditions (minimum angular frequency and maximum angular frequency).

Program P1 7 is an example program to generate this kind of signal.

```
% Program P1_7
% Generation of a swept frequency sinusoidal sequence
n = 0:100;
a = pi/2/100;
b = 0;
arg = a*n.*n + b*n;
x = cos(arg);
clf;
stem(n, x);
axis([0,100,-1.5,1.5]);
title('Swept-Frequency Sinusoidal Signal');
xlabel('Time index n');
ylabel('Amplitude');
grid; axis;
```

- **Questions:**

36) Q1.36 Run Program P1 7 and generate the swept-frequency sinusoidal sequence x[n].



37) Q1.37 What are the minimum and maximum frequencies of this signal?

La mínima es de 0 Hz y la máxima es de 0.5Hz. Ambas se calculan con la fórmula:

$$f = 2an + b$$

$$f_{min} = 2 * \frac{\frac{\pi}{2}}{100} * 0 + 0 = 0Hz$$

$$f_{max} = 2 * \frac{\frac{\pi}{2}}{100} * 100 + 0 = 0.5Hz$$

38) Q1.38 How can you modify the above program to generate a swept sinusoidal signal with a minimum frequency of 0.1 and a maximum frequency of 0.3?

$$\omega = 2\pi f$$

$$\omega_{\text{min}} = \mathrm{b}_{min} = 2\pi(0.1Hz) = \frac{\pi}{5}$$

$$\omega_{max} = b_{max} = 2\pi(0.3Hz) = \frac{3\pi}{5}$$