Important notes:

Groups of students with a maximum of 4 students per group

- The report should be Clear and Organized and must be commented.
- The Code must be Clear and Organized and must be commented.
- All figures should be correctly labeled.
- The cheater and cheatee of any part of the project will get 0 marks.
- The project is due 20/12/2025 at midnight.
- Late policy is -2 grades per day.
- The Hard Deadline is 22/12/2025 at midnight. No Submmition is allowed after it.
- The allowed Tool is Matlab.
- Any AI Tool is not allowed for coding.

Points will be deducted if any of the instructions above are not followed.

Project details

The project aims to introduce the students to the simulation of using Gram-Schmidt orthogonalization to analyze signal space signals.

Part 1:

- ## 1.1. Gram-Schmidt Orthogonalization:

Write a function that calculates the Gram-Schmidt orthonormal bases functions (ph1, phi 2, …., phi m) for two or more input signals (s_1 & $s_2, \ldots \ldots s_n$) each one of them is 1×N vector.

You can name the function { [Phis, m] = Basis_Cal (Signals, n) where, Phis is m×N, and m is the number of the bases functions, Signals is n×N, and n is the number of the signals}

- ## 1.2. Signal Space representation:

Write a function that calculates Signal Space representation for a given signal one orthonormal bases functions.

You can name the function { [signal_vector] = Signal_Rep (Phis, signal) where, signal_vector is 1×m}

- ## 1.3. Decision Boundaries:

Write a function that Draw the decision boundaries for the given signals one orthonormal bases functions. for only m = 1,2.
You can name the function { Decision_boundaries (Phis, Signals)}.
You can **use "scatter & scatter3" in Matlab.**

- ## 1.4. Signal Space Analysis:

Write a function that calculates the Euclidian Distance and cross correlation for a given signals and print All signals that have the minimum distance between them and the corresponding (distance, cross correlation).

- ## 1.5. AWGN in Signal Space:

Consider the Channel Add AWGN on the Signals with **zero mean and No/2 variance**
Write a function that can add AWGN noise to the signals then plot the noisy signals on signal space, (Label the original signals which are not suffer from the noise).

Part 2:

- ## 2.1. Hand Analysis Calculations:

Solve the Following Three Problems to help you to analyze your code

Problem 1:

$$S_1 = \begin{cases} -3 & 0 < t < 0.75 \\ 0.7 & 0.75 \leq t < 1 \end{cases}, \qquad S_2 = \begin{cases} 7.5 & 0 < t < 0.75 \\ -1.75 & 0.75 \leq t < 1 \end{cases}$$

Problem 2:

$$S_1 = \begin{cases} 1 & 0 < t < 1 \\ 0 & else \end{cases}, \qquad S_2 = \begin{cases} 1 & 0 < t < 0.75 \\ -1 & 0.75 \leq t < 1 \end{cases}$$

Problem 3:

$$S_1 = \begin{cases} 1 & 0 < t < 1 \\ 0 & else \end{cases}, \qquad s_2 = -s_1, \qquad S_3 = \begin{cases} 2 & 0 < t < 0.75 \\ 0.5 & 0.75 \leq t < 1 \end{cases}, \qquad s_4 = -s_3$$

- ## 2.2. Code Test 1:

Solve the Previous Three Problems by using your first 4 functions only. (hint use can use your sampling time ts= 40 ms).

- ## 2.3. Requirements:

1- Submit a single .PDF file that contains:
   a- Part 2.1 Hand Analysis.
   b- Part 2.2 Outputs (Signals Drawing, Basis Functions Drawings, Signal Space Coefficients in vector form, signals representation with Decision Boundaries, the min distances and it's signals)
   c- Noise Exercise.
   d- All your Codes at the end.
2- Submit a single Code file that contains all the parts
3- The figures in your report should be **clear**. **All figures** should have **a clear legend, and the axes should be properly labelled with proper font size.**
4- Please keep your report **neat, clean, and organized**.
5- **You are responsible** for the clarity and visibility of your figures, analysis, comments, code, etc.
6- Students must not copy any material from any reference (without proper citation), any another project or any AI tool. Plagiarism check shall be carried out, and the project will be considered invalid (fail) in case of plagiarism.

Noise Exercise:

For the following set of signals

$$S_1 = \begin{cases} 1 & 0 < t < 1 \\ 0 & else \end{cases}, \quad s_2 = -2s_1, \quad S_3 = \begin{cases} 1.5 & 0 < t < 0.75 \\ 0.7 & 0.75 \le t < 1 \end{cases}, \quad s_4 = -3s_3$$

Find the bases functions then draw the signals with decision boundaries the simulate your channel with noise like $\boldsymbol{E_1/N_o} = 10\,, 5\,, 0\,, -5\,, -10\ dB$, Which generate a (50 noisy sample) then plot then on the signals space representation.

Notes:

1- Make the original noiseless signal markers look like circles, while the noisy signal markers should look like crosses.

2- For each signal, create 50 noisy samples and plot them using the same color. You can use the scatter function in MATLAB.

3- Add a comment for each of the five figures explaining how the noise affects the signal and approximately how many errors occur.