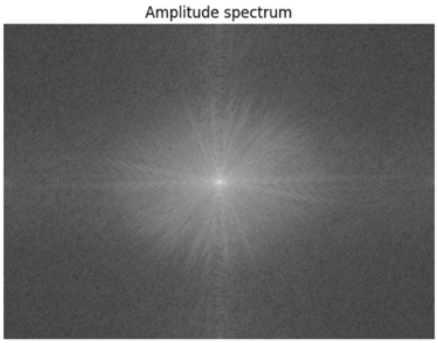
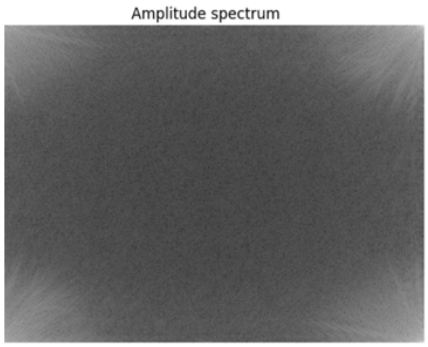
Your First and Last Name: **Total Marks: 100**

Image Representation (10 points)

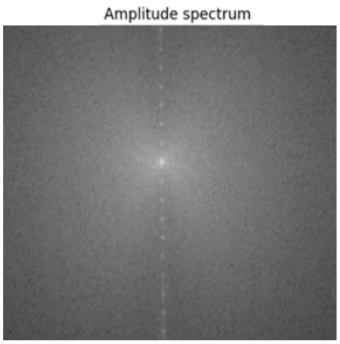
Question 1: What is Fourier transform shifting? Which of the following images is the result of Fourier transform shifting? (5 points)



(a)

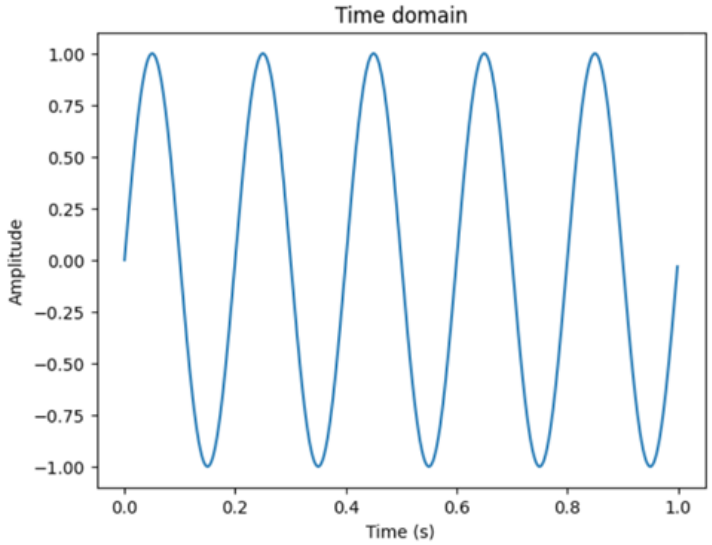


(b)



(c)

Question 2: Explain the Nyquist rate and illustrate it in the following plot. (5 points)



Audio Representation (25 points)

Question 3: The following mathematical equation represents the Short-Time Fourier Transform (STFT).

$$\textbf{STFT}\quad \hat{S}(k,m) = \sum_{t=0}^{N-1} f(t+mH)w(x).e^{-2\pi i t\frac{k}{N}}$$

Explain what the STFT is and define its components: m, H, w(x) and N. (15 points)

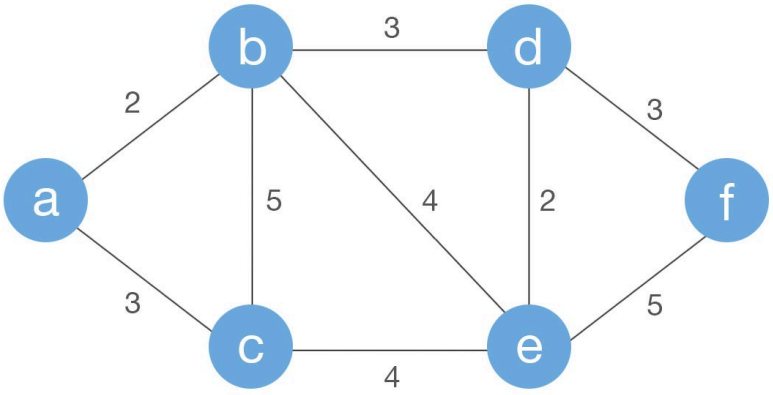
Question 4: Explain the difference between Short-Time Fourier Transform (STFT) and Fourier Transform (FT). (10 points)

Graph Representation (25 points)

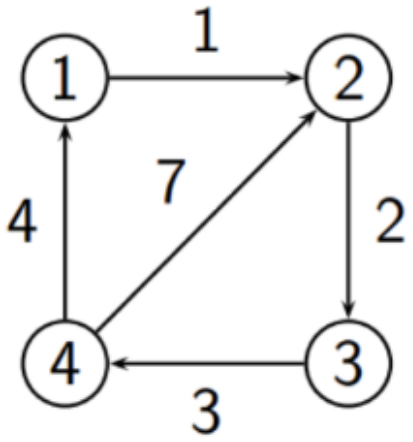
Question 5: Draw directed graph from incidence matrix: (5 points)

	E1	E2	E3	E4	E5	E6	E7	E8
A	1	1	-1	0	0	0	0	0
B	-1	0	0	1	0	1	0	0
C	0	-1	0	0	1	0	0	0
D	0	0	1	-1	-1	0	1	1
E	0	0	0	0	0	-1	-1	0

Question 6: Find the minimal spanning trees for the following graph using Prim's algorithm: (5 points)



Question 7: Given a graph, use Floyd's algorithm to find the shortest path for i=1, j=2, and k=4: (15 points)



$$D^k[i,j] = \min[D^{k-1}[i,j], D^{k-1}[i,k] + D^{k-1}[k,j]$$

Where i represents the row, j represents the column, and k represents the vertex.

Data Representation for Machine Learning (30 points)

Question 8: You are working with a manufacturer to optimize a design for a

wooden bench. You want to choose a design that can be reliably used by a 200 pound person. Your 500 stress test records include: **(8 points)**

- Wood thickness (**T**)
- Number of hours of repetitive use by a 200-pound test weight before failure (**F**)
- Number of screws attaching the legs (**N**)
- Bench color **(C)**
- Name of employees **(I)**
- Diameter of the screws attaching the legs (**D**)
- Length of the screws attaching the legs (**L**)

You want to predict how long the bench can be used before failure.

a. **Is this a regression, clustering, classification, or other type of problem?** (1 points)
b. **Decide whether each item (T, F, N, C, I, D, L) is a meaningful feature (independent) , label (dependent), or neither.** (3 points)
c. **Which single metric would best help you evaluate the quality of your model?** (2 points)
d. **For your metric *m*, what would you interpret as a good score / good model?** (2 points)

Question 9: Answer the following questions: **(17 points)**

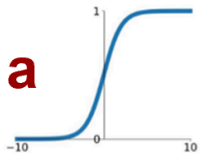
a. Define what an Artificial Neural Network (ANN) is (2 points).
b. Outline the basic architecture of a neural network by providing a visual representation. Consider a scenario with 5 input neurons and the creation of 2 hidden layers. The first hidden layer consists of 4 neurons, and the second hidden layer has two neurons. Clearly illustrate the placement of activation functions and the application of weights within this architecture (6 points).
c. Provide one method to initialize the weights. Explain briefly how it works (3 points).
d. To mitigate overfitting, suggest one solution. Explain briefly how it works (3 points).
e. What is the loss function in a Neural Network (NN)? How can we optimize the loss in NN? Name one optimizer and explain how it works.(3 points)

Question 10: There are 4 activation functions, each with the following metrics: **(5 points)**

a. Explain what ∅ and z are in these equations? (2 points)
b. Explain the functionality of one of these activation functions? (3 points)

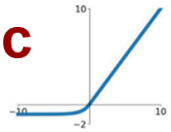
$$\phi(z) = \frac{1}{1 + e^{-z}}$$

a



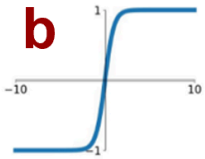
$$\begin{cases} \phi(z) = z & z \geq 0 \\ \phi(z) = \alpha(e^z - 1) & z < 0 \end{cases}$$

c



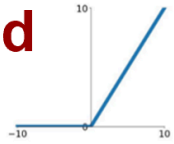
$$\phi(z) = \tanh(z)$$

b



$$\phi(z) = \max(0, z)$$

d



Data Dimensionality Reduction (10 points)

Question 11: Explain the curse of dimensionality and its implications in machine learning. How does dimensionality reduction help to solve this issue? (5 points)

Question 12: Describe two main categories of dimensionality reduction techniques commonly used in machine learning. Provide an example technique for each category. (5 points)