# 2025 USA-NA-AIO Round 1, Problem 2, Part 1

**USAAIO** 🛡　　　　　　　　　　　　　　　　　　**Mar 2025**

## Problem 2 (100 points)

This problem is about the basics of neural network.

Before starting this problem, make sure to run the following code first **without change**:

```python
""" DO NOT CHANGE """
import numpy as np
import matplotlib.pyplot as plt
import torch
import torch.nn as nn
import torch.optim as optim
torch.manual_seed(2025)
```

WARNING !!!

- Beyond importing libraries/modules/classes/functions in the preceeding cell, you are **NOT allowed to import anything else for the following purposes**:

  - **As a part of your final solution.** For instance, if a problem asks you to build a model without using sklearn but you use it, then you will not earn points.

  - **Temporarily import something to assist you to get a solution.** For instance, if a problem asks you to manually compute eigenvalues but you temporarily use `np.linalg.eig` to get an answer and then delete your code, then you violate the rule.

**Rule of thumb:** Each part has its particular purpose to intentionally test you something. Do not attempt to find a shortcut to circumvent the rule.

- All coding tasks shall run on CPUs, **not GPUs**.

## Part 1 (5 points, non-coding task)

The high level idea of affine transformation in math is that for each column vector $\mathbf{x} \in \mathbb{R}^N$, an affine transformation maps it to another column vector $\mathbf{y} \in \mathbb{R}^M$ via

$$\mathbf{y} = \mathbf{W}\mathbf{x} + \mathbf{b},$$

where

- $\mathbf{W} \in \mathbb{R}^{M \times N}$.

- $\mathbf{b} \in \mathbb{R}^M$.

Now, let us study a small-sized problem.

Let

$$\mathbf{W} = \begin{bmatrix} 2 & -3 & 1 & 3 & -2 \\ 0 & 1 & 2 & 5 & -1 \\ 7 & -1 & -3 & 7 & 0 \end{bmatrix}$$

and

$$\mathbf{b} = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}$$

and

$$\mathbf{x} = \begin{bmatrix} 1 \\ 2 \\ -3 \\ 1 \\ -2 \end{bmatrix}$$

**Answer the following questions:**

1. What is the value of $N$?

2. What is the value of $M$?

3. What is the value of $\mathbf{y}$.

Questions 1 and 2 do not require reasoning. Question 3 requires reasoning.

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