



What are Tensors in Machine Learning?

A **tensor** is simply a **data container** used to store numbers in machine learning.

👉 Think of tensors as a **generalized form of arrays** (like in Python/NumPy).

- A **scalar** → single number
- A **vector** → list of numbers
- A **matrix** → table of numbers
- A **tensor** → anything beyond that (or all of them together!)

📌 In ML & Deep Learning, *everything* is represented as tensors

(images, text, audio, model weights, inputs, outputs, gradients... everything!)

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Why Tensors Are Important in ML

- ML models do **mathematical operations** on data
- Those operations need structured numeric data
- Tensors provide:
 - Shape
 - Dimensions
 - Efficient computation (CPU/GPU/TPU)

Frameworks like **TensorFlow** and **PyTorch** are literally built around tensors.



Types of Tensors (Based on Dimensions / Rank)

The **rank** of a tensor = number of dimensions

1

Scalar (0-D Tensor)

- **Single number**

- Rank = 0

📌 Example:

```
5
3.14
-10
```

📌 Use cases:

- Learning rate
- Loss value
- Bias term

2 Vector (1-D Tensor)

- **List of numbers**
- Rank = 1

📌 Example:

```
[ 2 , 4 , 6 , 8 ]
```

📌 Use cases:

- Feature vector
- Word embeddings
- Output probabilities

3 Matrix (2-D Tensor)

- **Rows × Columns**
- Rank = 2

📌 Example:

```
[
  [ 1 , 2 , 3 ] ,
  [ 4 , 5 , 6 ]
]
```

📌 Use cases:

- Dataset (samples \times features)
- Weight matrices in neural networks
- Images in grayscale (height \times width)

4 3-D Tensor

- Stack of matrices
- Rank = 3

 Example:

`(height \times width \times channels)`

 Use cases:

- **Color images** (RGB)
- Time-series data
- Word sequences

 Example (Image):

`64 \times 64 \times 3`

(height, width, RGB channels)

5 4-D Tensor

- Common in **deep learning**
- Rank = 4

 Example:

`(batch_size \times height \times width \times channels)`

 Use cases:

- Batch of images fed to CNNs

 Example:

`32 \times 64 \times 64 \times 3`

→ 32 images, each 64x64 RGB

6 Higher-Dimensional Tensors (5-D, 6-D...)

Used in:

- Video processing 
- Medical imaging 
- NLP transformer models 

📌 Example (Video data):

(batch × frames × height × width × channels)

🧩 Tensor Types Based on Data

Tensors can also differ by **what kind of data they store**:

Type	Example
Integer tensor	class labels
Float tensor	images, weights
Boolean tensor	masks
String tensor	text (before encoding)

🔥 Tensors vs Arrays (Important!)

Feature	NumPy Array	Tensor
GPU support	✗	✓
Automatic differentiation	✗	✓
Used in deep learning	⚠ Limited	✓

That's why ML frameworks use tensors instead of plain arrays.

🧠 Simple Mental Model (Exam-Friendly)

Tensor = Multi-dimensional numerical data structure used to represent and process data in machine learning models

✨ One-Line Summary

- Scalar → 0D
- Vector → 1D
- Matrix → 2D
- Image → 3D
- Batch of images → 4D
- Video → 5D+